A SUMMARY OF AEROLOGICAL OBSERVATIONS MADE IN WELL-PRONOUNCED HIGHS AND LOWS

551.515

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SYNOPSIS

The primary purpose in preparing this paper has been to determine the oustanding characteristics of *well-pronounced* HIGHS and LOWS as well as such features as distinguish them from each other. The mean free-air winds, temperatures, relative humidities and vapor pressures were determined for summer and winter at a number of stations in the United States for the four quadrants and the center of each pressure system. An accurate comparison of the two methods of observation, viz, kite and pilot balloon, was made possible by summarizing these data separately.

INTRODUCTION

It is recognized that mean values tend to conceal important characteristics peculiar to individual HIGHS and LOWS, which must in themselves be analyzed in any study of the fundamental mechanics involved. However, averages based on the more typical cases have their uses and are necessary in determining basic values, so that departures therefrom may not only be more readily identified but their significance better realized as well. The relative importance of the various physical processes involved in producing the mean values is seldom if ever the same in the individual cases and therefore the discussion of these means will be limited mostly to statements of facts supplementary to the illustrations and tables.

This paper on the free-air conditions associated with certain types of pressure distribution as depicted on the daily weather maps is based on observations made at approximately the time represented on the maps, viz, 8 a. m., 75th meridian time. The stations and periods of record used are shown in Table 1.

TABLE 1

KITE OBSERVATIONS

Station	Altitude (m.), m. s. l.	Latitude (N.)		Longitude (W.)		Period of record (inclusive) From—	To—	Years	Months
		°	′	°	′				
Broken Arrow, Okla.	233	36	02	95	49	Aug., 1918	Sept., 1924	6	2
Drexel, Nebr.	396	41	20	96	16	Nov., 1915	do	8	11
Due West, S. C.	217	34	21	82	22	Mar., 1921	do	3	7
Ellendale, N. Dak.	444	45	59	98	34	Jan., 1918	do	6	10
Groesbeck, Tex.	141	31	30	96	28	Oct., 1918	do	6	0
Leesburg, Ga.	85	31	47	84	14	Mar., 1919	June, 1920	1	4
Royal Center, Ind.	225	40	53	86	29	July, 1918	Sept., 1924	6	3

PILOT-BALLOON OBSERVATIONS

Station	Altitude (m.), m. s. l.	Latitude (N.)		Longitude (W.)		From—	To—	Years	Months
Broken Arrow, Okla.	235	36	02	95	49	Oct., 1918	Sept., 1924	6	0
Burlington, Vt.	132	44	29	73	13	Nov., 1919	July, 1921	1	9
Denver, Colo.	1,620	39	48	105	00	do	do	1	9
Drexel, Nebr.	396	41	20	96	16	Nov., 1921	Sept., 1924	2	11
Due West, S. C.	217	34	21	82	22	Dec., 1920	do	3	10
Ellendale, N. Dak.	442	45	59	98	34	Oct., 1918	do	6	0
Groesbeck, Tex.	139	31	30	96	28	do	do	6	0
Ithaca, N. Y.	291	42	26	76	34	July, 1919	July, 1921	2	1
Key West, Fla.	11	24	33	81	48	July, 1920	Sept., 1924	4	3
Lansing, Mich.	263	42	45	84	38	June, 1919	July, 1921	2	2
Leesburg, Ga.	84	31	47	84	14	Oct., 1918	Sept., 1920	2	0
Madison, Wis.	307	43	03	89	18	May, 1919	July, 1921	2	3
Royal Center, Ind.	228	40	53	86	29	Oct., 1918	Sept., 1924	6	0
Washington, D. C.	34	38	53	77	31	Dec., 1918	do	5	10

Kite and pilot-balloon observations have been classified separately according to the position of the station with reference to the center of well-pronounced HIGHS and LOWS, as shown on the morning weather maps. By well pronounced HIGHS and LOWS is meant those pressure areas having in general a concentric system of three or more isobars and a gradient of at least 0.1 inch per 200 miles in the region where the isobars are nearest together. It is believed that a smaller number of observations made under *well-pronounced* pressure conditions are, for purposes of determining outstanding and distinctive characteristics of HIGHS and LOWS, superior to a greater number that would necessarily include many cases with poorly defined pressure distribution. Hence only such pressure areas were considered as unquestionably had a controlling influence over the station, i. e., the latter was situated *within* the concentric system of isobars about the center. Hereafter all references to HIGHS and LOWS are to the *well-pronounced* types only.

Those pressure areas selected were divided into quadrants and the center, designated as follows: I–NE, II–NW, III–SW, IV–SE and center. (See fig. 17.) By such a division, the first and fourth quadrants imply, in general, the front sector and the second and third quadrants the rear sector of the pressure area. This, of course, is true only when the direction of movement of the pressure area is toward the east, but since a westerly direction in these regions is so rare this nomenclature, it is believed, will not lead to confusion in the consideration of the mean values shown here.

Pilot-balloon observations have been referred to ground level and kite observations to sea level. In the latter the ascents only were used, in order to secure a record of conditions as nearly simultaneous as possible. The average time required for the kite to reach its maximum altitude was about two hours and since the ordinary diurnal variation during this interval is most pronounced at the surface and diminishes with altitude to about 500 m., above which it is usually very small, the observations may be regarded as practically simultaneous for free-air levels.

It is evident that the location of a station, with respect to the most frequented tracks of HIGHS and LOWS, determines to a large extent the quadrants best represented in a classification of this kind. Another factor, however, is the weather conditions associated with certain quadrants, some being more favorable than others for making aerological observations. In order, therefore, that a general perspective of the net results in this regard may be obtained, Figures 1 to 8 have been prepared.

In no case has any quadrant been considered sufficiently represented to be included in the charts unless five or more observations were obtained within it. Owing to the limited number of observations, only two seasons were used, viz, summer (June, July, August, and September) and winter (December, January, February, and March).

It may be questioned whether mean values based on so small a number of observations as were here used, especially for some quadrants, are properly representative. Although a longer series would very likely alter these means to some extent, yet in their present form they are certainly significant for comparison since they represent the more pronounced pressure types. Furthermore, the relatively large number of stations making aerological observations affords opportunity to compare the results for corresponding quadrants, thereby providing a check against any appreciable error which might occur if the records from *one* station only were being used. On the whole, it is believed that these averages may be safely accepted qualitatively and, except in those cases where the number of observations is comparatively small, in a fairly reliable quantitative degree as well.

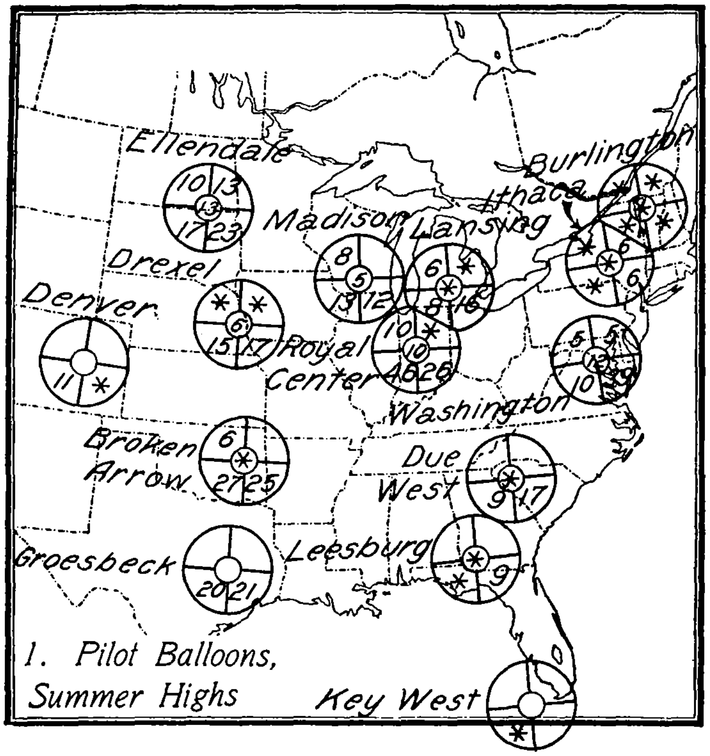


FIG. 1

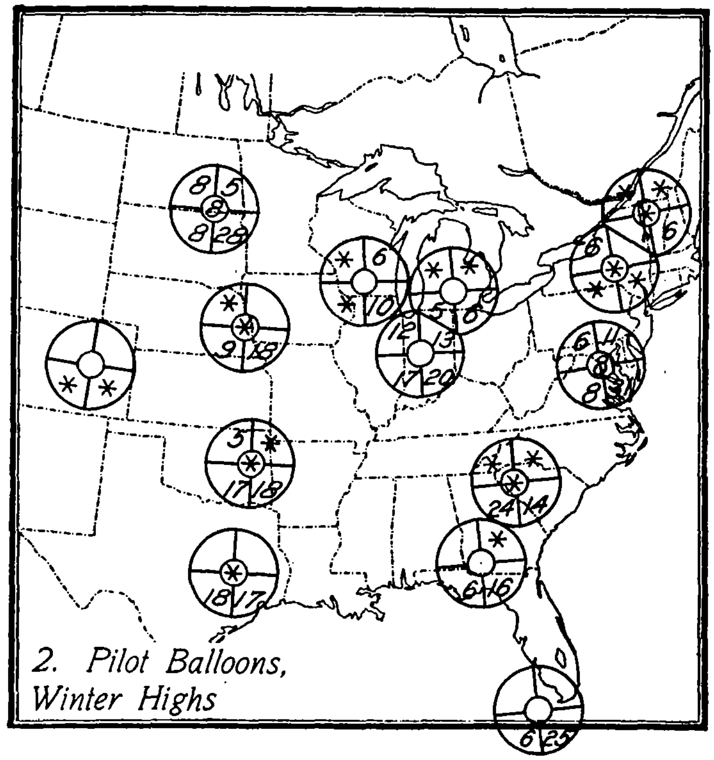


FIG. 2

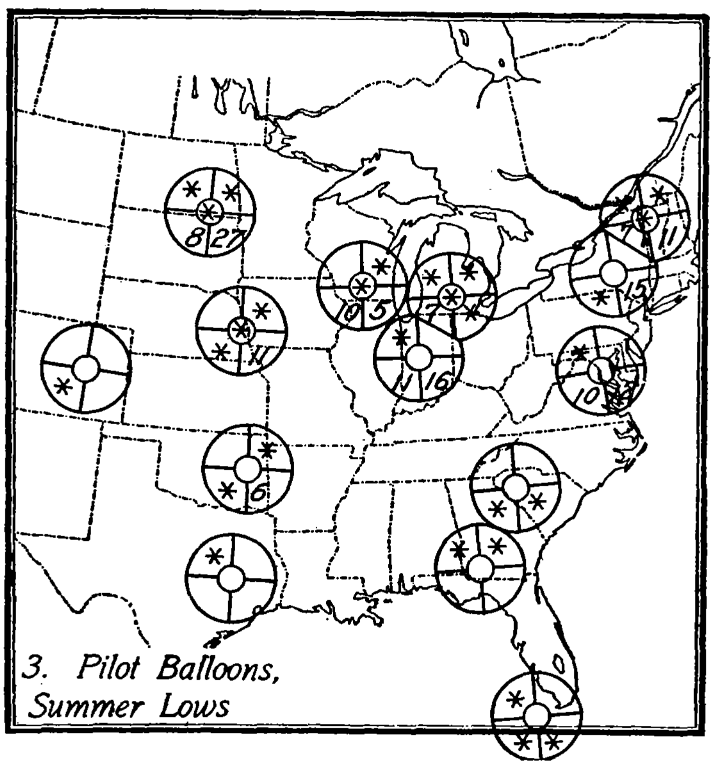


FIG. 3

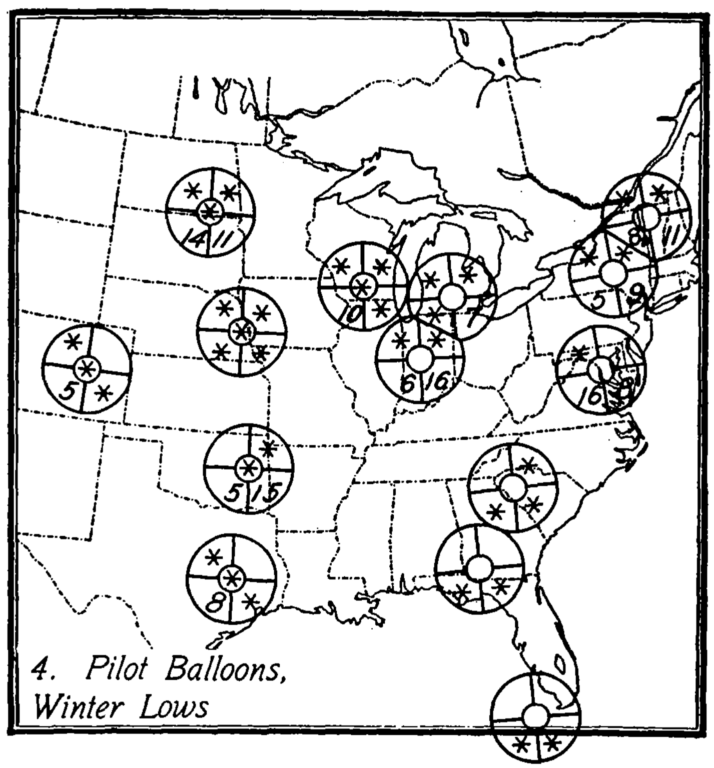
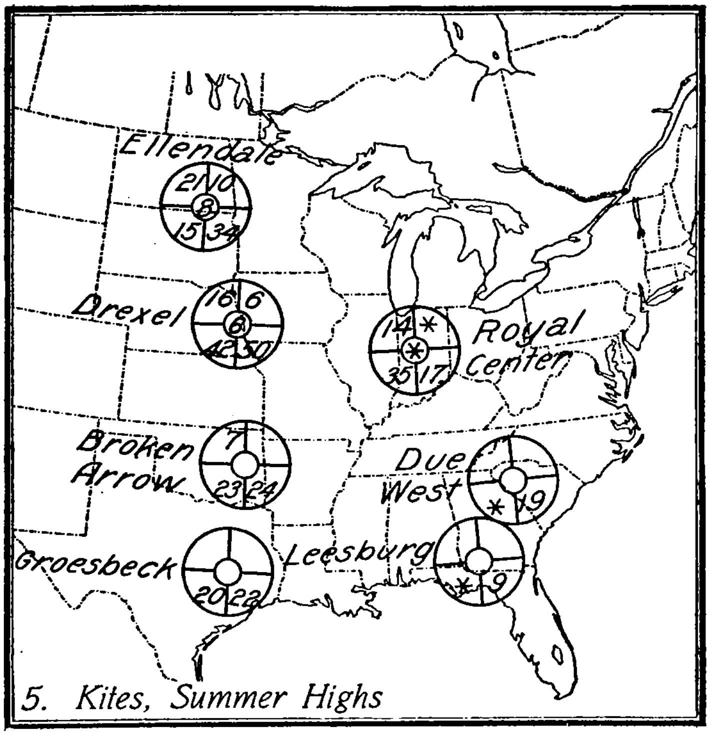


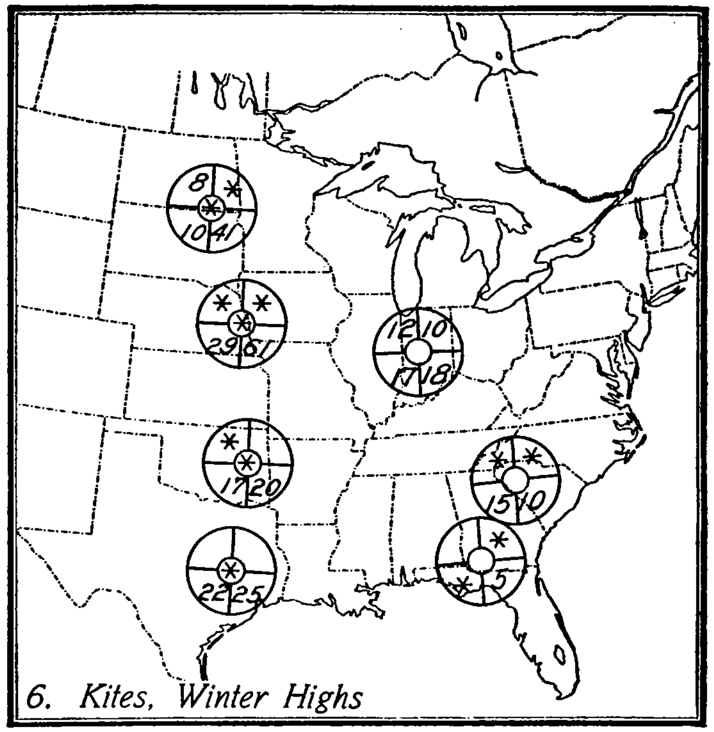
FIG. 4

FIGS. 1-8.—Number of observations in various quadrants and the center of well pronounced HIGHS and LOWS in summer and winter, on which are based the mean values shown in subsequent graphs and tables. (A * indicates less than five observations; their means, therefore, are not included.) (For Figs. 5-8, see opposite page.)



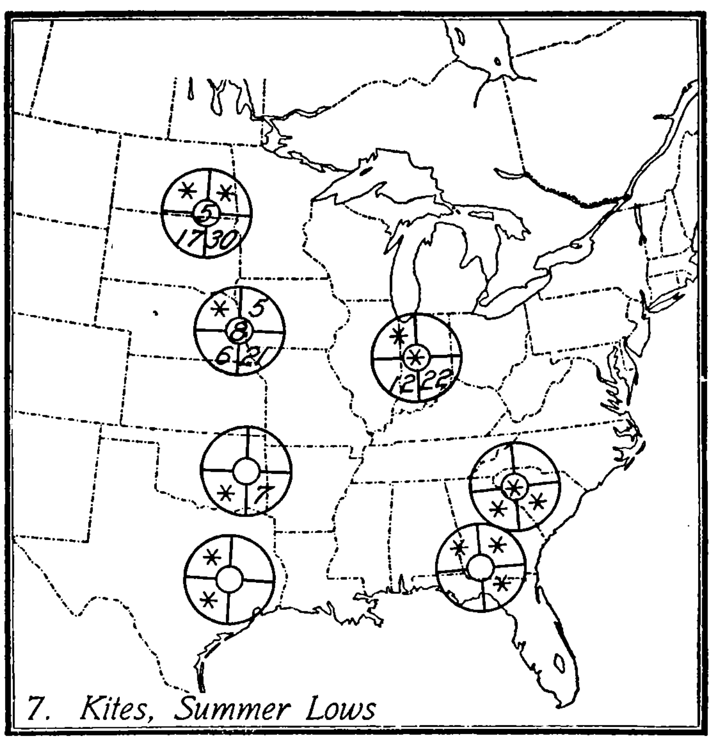
5. Kites, Summer Highs

FIG. 5



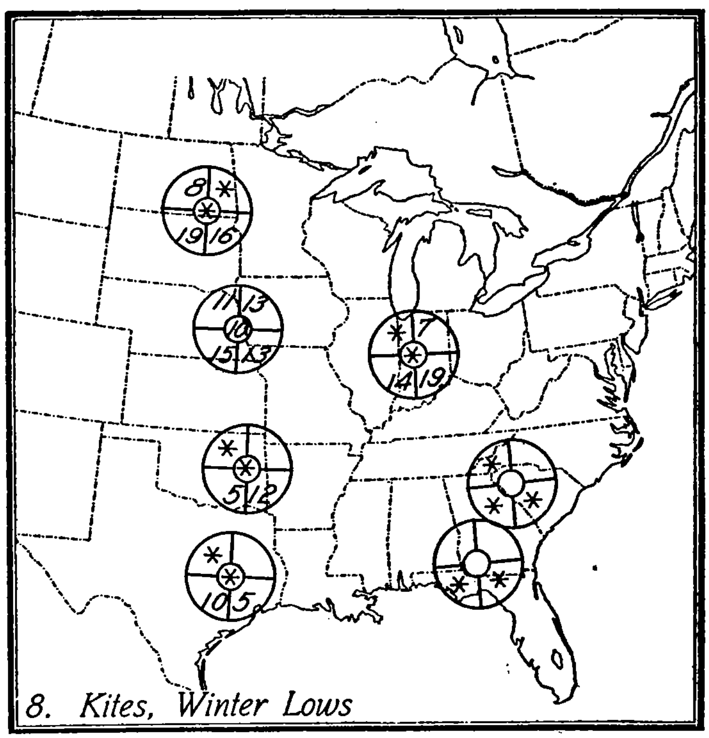
6. Kites, Winter Highs

FIG. 6



7. Kites, Summer Lows

FIG. 7



8. Kites, Winter Lows

FIG. 8

The practicability of securing these observations, due to the seasonal variation in the tracks of HIGHS and LOWS, may be noted in the large number of pilot-balloon observations at Key West for the fourth quadrant of HIGHS during winter as compared with none for the same quadrant during summer. (See figs. 1 and 2.) The failure to secure either kite or pilot-balloon observations at any station within the first or second quadrant of LOWS owing to unfavorable weather conditions in that sector is well brought out in Figures 3, 4, 7, and 8.

Mean wind velocities and directions as determined from both kite and pilot-balloon observations separately have been included for the following reasons:

1. Since all of these observations were made under special weather conditions, any inherent characteristics of either method will therefore be more conspicuous than if made under a variety of pressure types.

2. The kite observations outnumber the balloon observations in certain quadrants, but the latter extend in general to greater heights.

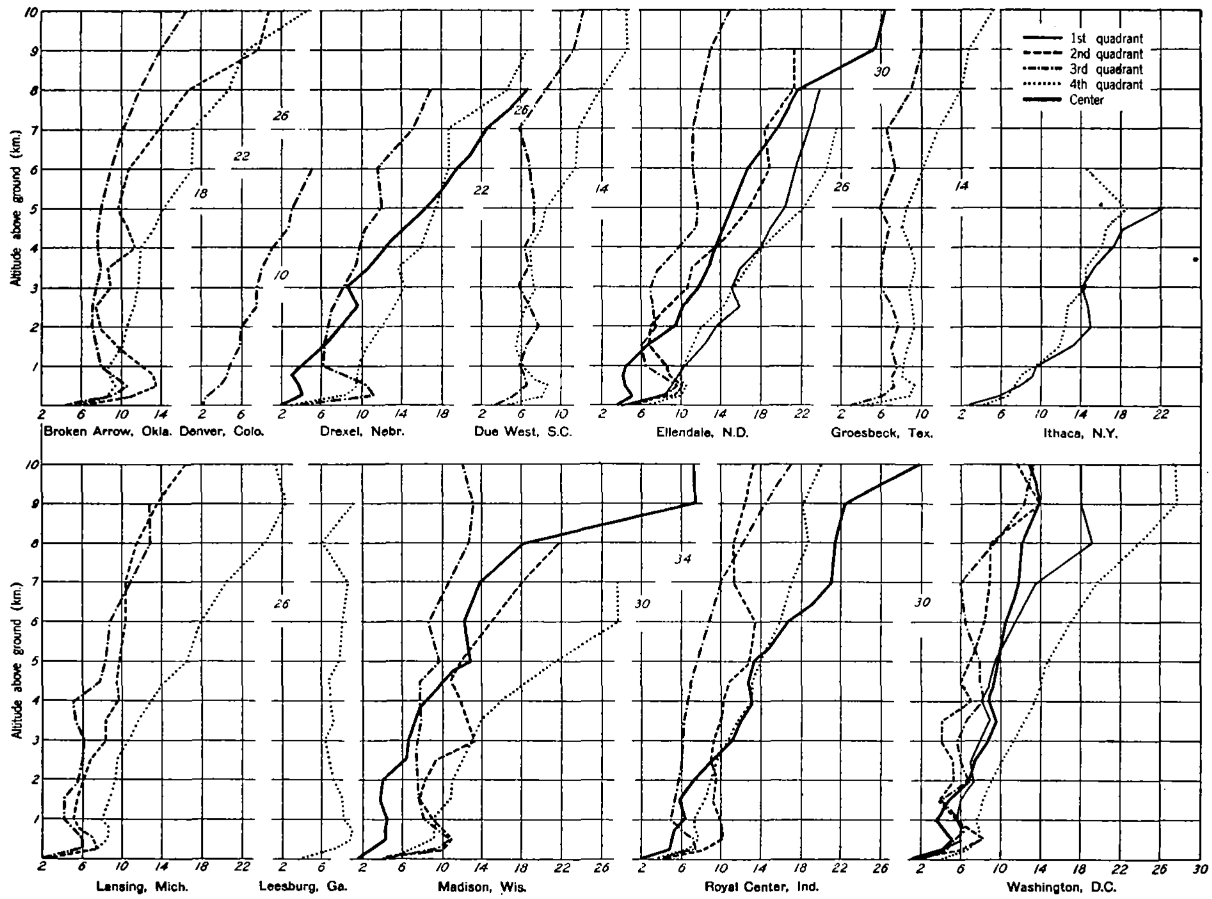


FIG. 9.—Mean wind velocities (m. p. s.) as determined from pilot-balloon observations in various quadrants of well-pronounced HIGHS during summer

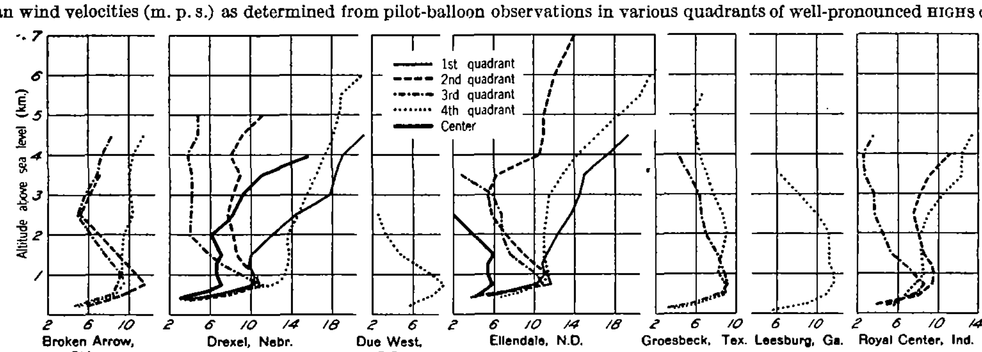


FIG. 10.—Mean wind velocities (m. p. s.) from kite observations in summer HIGHS

In view of the gradual decrease with altitude in the number of observations it is necessary in computing averages for the upper levels [1] to add the mean gradients between successive levels to the mean for the surface.

It is believed that data of this nature are most advantageously analyzed when viewed graphically. Numerous graphs are therefore reproduced and tables omitted or condensed so far as practicable.

[1] The general terms, "lower" and "upper" levels of HIGHS and LOWS are frequently used throughout this paper and although the dividing level between these two regions is arbitrary it refers, in general, to an altitude between 1 and 2 km.

3. Certain quadrants at some of the stations are represented by kite observations only, other quadrants by balloon observations alone. By having both sets in these cases, all possible quadrants are included.

WIND VELOCITY

The mean wind velocities determined from pilot-balloon and kite observations in various quadrants of HIGHS and LOWS for summer and winter are shown in Figures 9 to 16, inclusive.

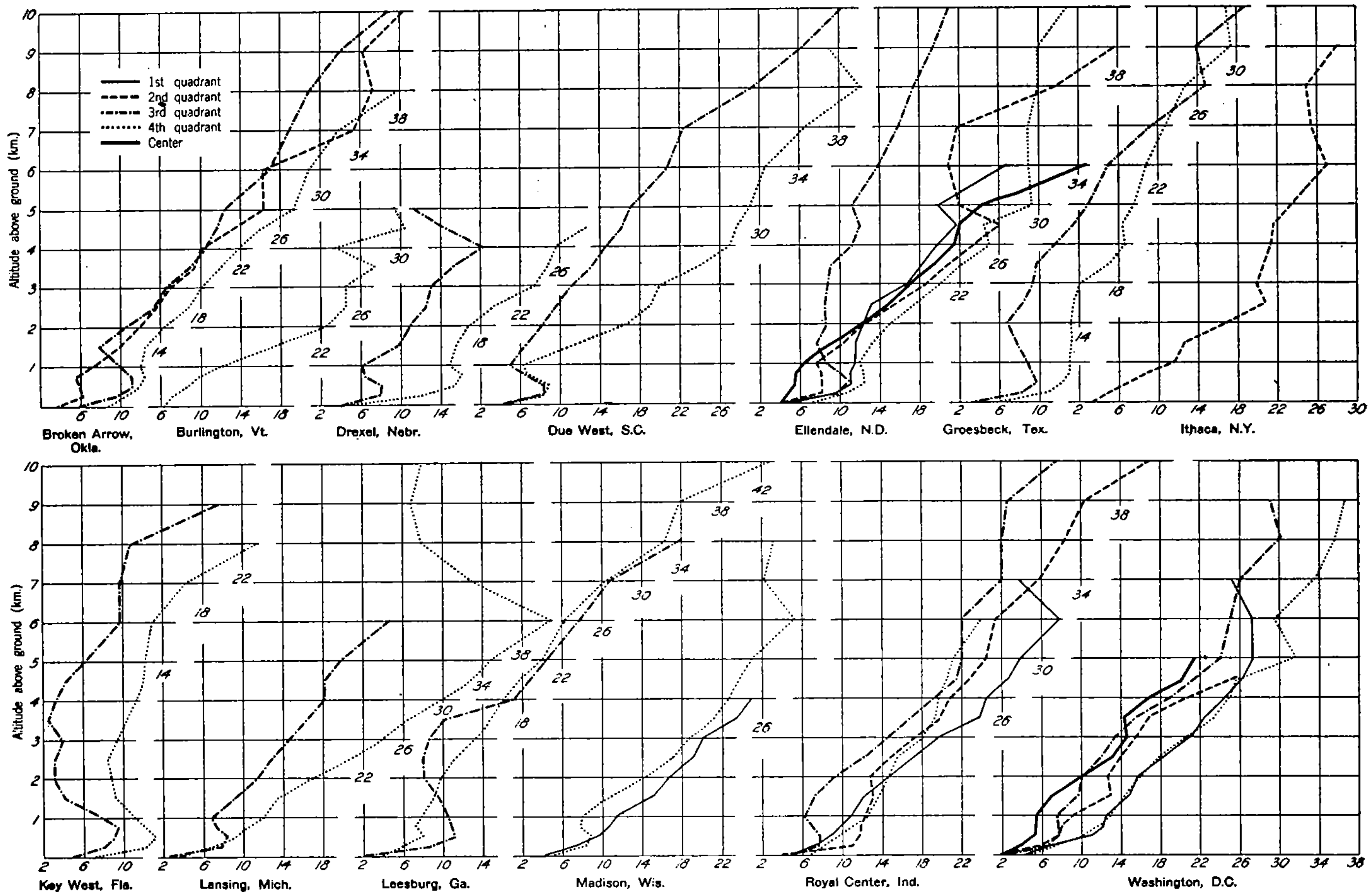


FIG. 11.—Mean wind velocities (m. p. s.) from pilot-balloon observations in winter HIGHS

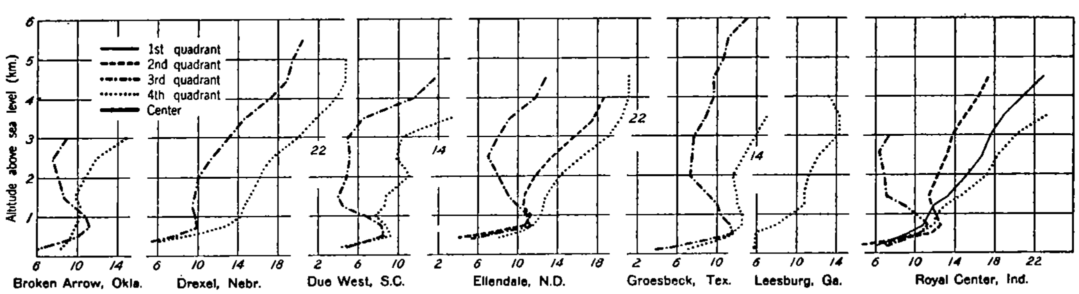


FIG. 12.—Mean wind velocities (m. p. s.) from kite observations in winter HIGHS

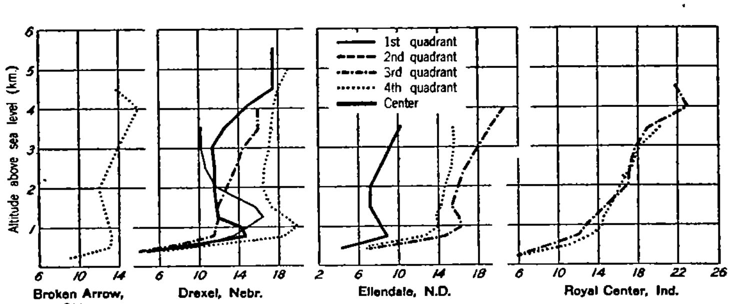


FIG. 14.—Mean wind velocities (m. p. s.) from kite observations in summer LOWS

The general agreement between the mean velocities determined separately from pilot-balloon and kite observations is very close. It will be seen however that in HIGHS the kite observations indicate generally slightly greater values for the lower levels and slightly lesser values for the upper. The first relationship is explained by the fact that in HIGHS, the lower winds are frequently too light for kite flying; the second is evidently due to the abrupt shifts in wind direction occurring with a marked decrease in velocity at their boundaries, which often make it impossible for the kites to rise into the swifter currents above. Such conditions are frequently shown by pilot-balloon observations to occur in the upper levels of HIGHS. Another factor, however, is that the kites are often beaten down by high winds aloft.

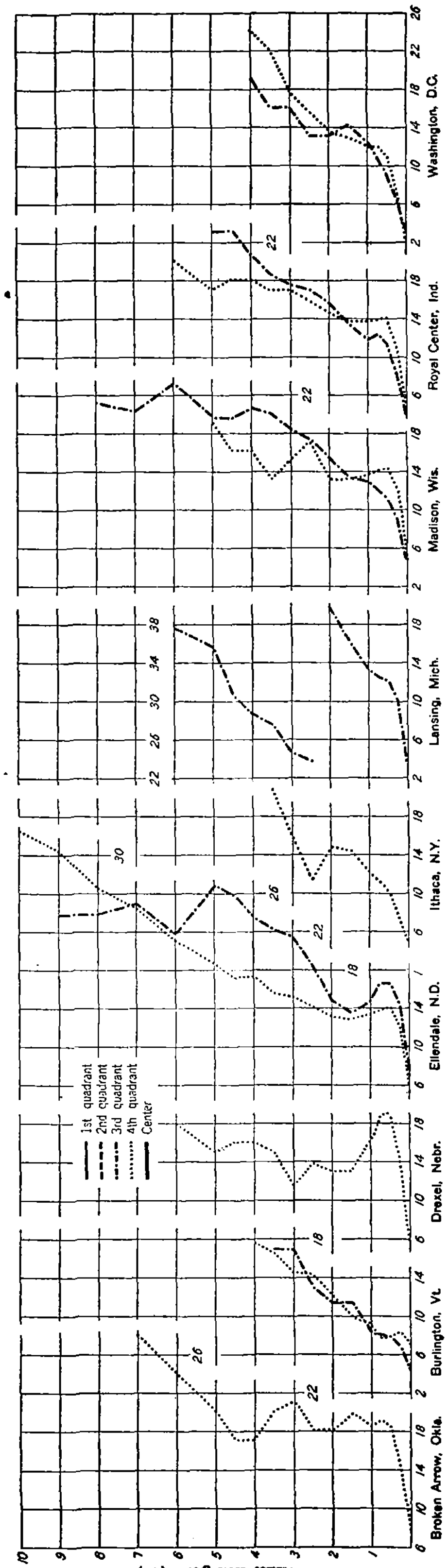


FIG. 13.—Mean wind velocities (m. p. s.) from pilot-balloon observations in summer LOWS

This relationship between the two methods of observation is evidently not the same in LOWS, there being no consistent difference in their lower levels. In the upper levels the pilot-balloon observations indicate generally higher values, the differences, however, being smaller than in the case of HIGHS. The first relationship is explained by the fact that in the lower levels of LOWS there do not occur the frequent light winds which prevent kite flights as is the case in HIGHS; as to the second relationship, it seems that abrupt shifts in wind direction are less pronounced in LOWS than in HIGHS, at least in those quadrants most favorable for aerological observations, and therefore the altitudes reached by the kites are not so often limited by this cause.

The seasonal differences between the mean wind velocities in HIGHS and in LOWS clearly indicate higher values in winter than in summer, the differences being considerably greater in the upper than in the lower levels of both pressure systems.

The mean wind velocities are shown to be greater in LOWS than for the same levels and seasons in adjacent sectors[2] of HIGHS.

For the lower levels of HIGHS the sequence in which the quadrants fall in passing from the quadrant of minimum velocity to that of maximum, varies considerably at different stations. An exception, however, occurs in the case of the curves representing the *center* of HIGHS, which consistently indicate for the lower levels at all stations, a *lower* mean wind velocity than is found for any quadrant. The mean velocity for the upper levels of the central region of HIGHS, however, closely approaches the mean values for the same levels of those quadrants of HIGHS containing the *highest* velocities. This might well be expected, since the necessarily light winds, at and near the surface, characteristic of the central region of HIGHS would disappear in the upper levels where a markedly different pressure distribution usually prevails.

The rapid increase in the mean wind velocity with increase in height through the first few hundred meters above ground in HIGHS and in LOWS is a result of the diminishing effect of friction and turbulence. The rate of increase throughout this ground stratum, in most cases, *greatly exceeds that for any of the higher strata*. It is greater in LOWS than in HIGHS for the same season and greater in winter than in summer in both HIGHS and LOWS.

Immediately above this ground layer, which on the

[2] The term "adjacent sectors" is used here to designate those regions of HIGHS and LOWS wherein the same general wind direction in their lower levels is indicated, i. e., the front sector of HIGHS and the rear sector of LOWS, wherein, this direction is northerly and, the rear sector of HIGHS and the front sector of LOWS wherein, this direction is southerly.

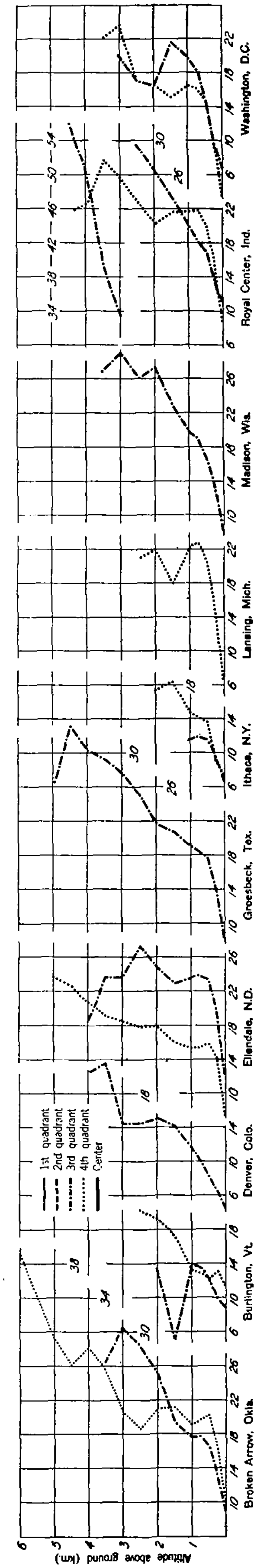


FIG. 15.—Mean wind velocities (m. p. s.) from pilot-balloon observations in winter LOWS

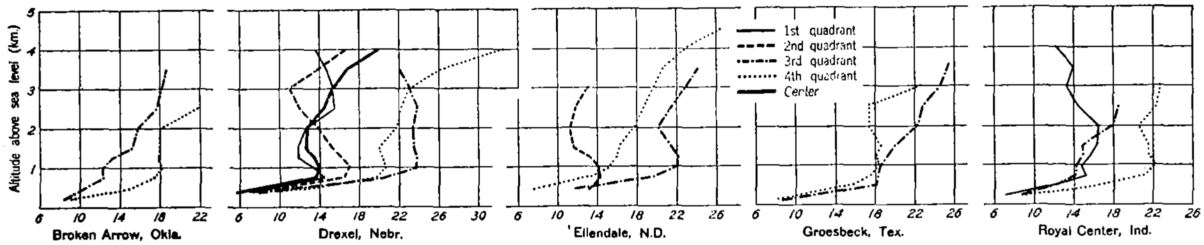


FIG. 16.—Mean wind velocities (m. p. s.) from kite observations in winter LOWS

average is about 500 m. thick, there will be noted a stratum of varying thickness in which occurs a more or less abrupt *decrease* in the mean wind velocity. This decrease is most pronounced in the second and third quadrants of HIGHS and in the first and second quadrants of LOWS, i. e., where the change in the mean wind direction with altitude is greatest. (See figs. 18 to 25.) From this it is evident that abrupt changes in wind direction with altitude doubtless have an important bearing on the average decrease referred to above. That they are not wholly the cause, however, is demonstrated by the fact that in individual observations such an abrupt decrease in velocity frequently occurs independently of any change in wind direction. This decrease is much more in evidence in the morning than in the afternoon, the effect of convection tending to destroy any such stratification in the lower atmosphere. This characteristic decrease in the wind velocity with altitude is found alike at northern and southern stations and must, in general, be attributed to marked changes in the horizontal pressure gradient with height. It is well known that the sea-level pressure distribution may be considerably different from that, prevailing at various heights above, and therefore the frequency with which this difference occurs must influence the mean values to the extent shown by the velocity curves. The fact that this decrease is more pronounced in certain sectors of HIGHS and LOWS than in others is doubtless due to the larger and more frequent abrupt shifts in wind direction characteristic of those sectors.

The close convergence of the curves at their bottom stands in marked contrast to the divergence at the top. The former strikingly reveals the almost inconsequential differences between the mean velocities for the various quadrants near the ground, whereas the latter is partly actual and partly a result of the fact that the extreme range in wind velocity is considerably greater in the upper levels than in the lower and therefore a greater number of observations are required to determine the *true* mean for the higher levels.

The latitudinal differences in the mean wind velocities in both HIGHS and LOWS are considerably greater for their upper than for their lower levels in both seasons.

The wind velocities in the upper levels of HIGHS average higher in their first and fourth quadrants than in their second and third, whereas in the upper levels of LOWS they are higher in the third and fourth quadrants than in the first and second. This relationship is to be expected since it is well known that the average change in the direction of the pressure gradient with increase in elevation (as indicated by the average wind directions) is considerably *less* in the first and fourth quadrants of HIGHS and in the third and fourth quadrants of LOWS than in the second and third quadrants of HIGHS and in the first and second quadrants of LOWS.

The relationship between HIGHS and LOWS, in this connection, is shown graphically in Figure 17, where it may be seen that agreement occurs at but two of the four points of tangency, viz, in the first quadrant of HIGHS and third quadrant of LOWS, where relatively strong winds are prevalent in both pressure systems, and again, in the third quadrant of HIGHS and first quadrant of LOWS, where the winds are correspondingly light.

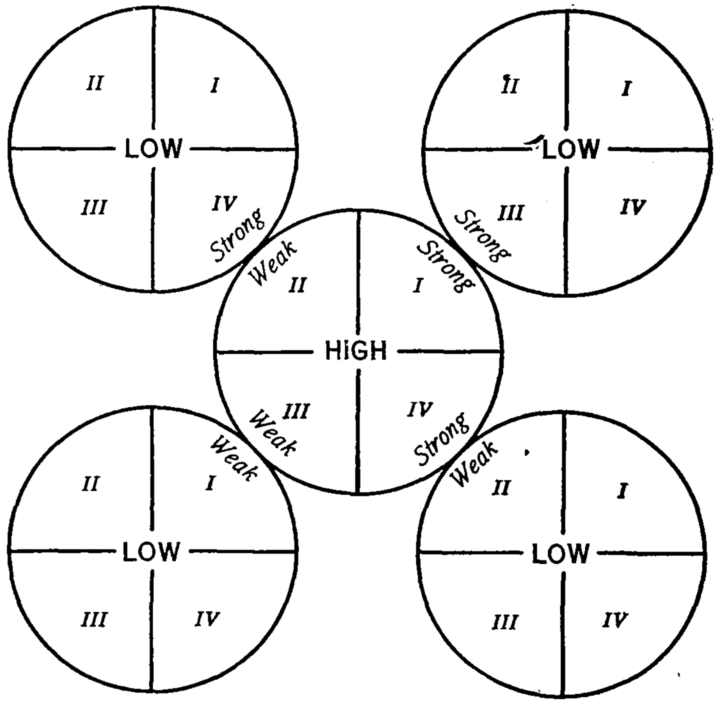


FIG. 17.—A graphical comparison of the relationship between the mean wind velocities above the gradient wind level for adjacent quadrants of well pronounced HIGHS and LOWS

Dr. Albert Peppler (*1*) has compiled the mean wind velocities and gradients for the various quadrants of HIGHS and LOWS as obtained from kite observations made at Lindenburg, lat. N. 52° 10′; long. E. 14° 15′, from 1903 to 1908. A comparison of these results was made with those given in this paper. The number of observations used by Peppler was considerably greater than that used here, but it must be remembered that the German data do not strictly represent what have here been called *well-pronounced* HIGHS and LOWS but rather the more common but less pronounced types characteristic of the middle latitudes. Moreover, Peppler used the *means* of the ascents and descents of the kite flights whereas here, only the ascents have been used.

A close parallelism between the two sets of data is further made improbable owing to the fact that in the German study the pressure areas were divided into N., W., S., and E. quadrants while in this study the NE., NW., SW., and SE. quadrants were used. It would seem that in general with the former division the trajectories of the air currents would show greater diversity in the individual quadrants than with the latter.

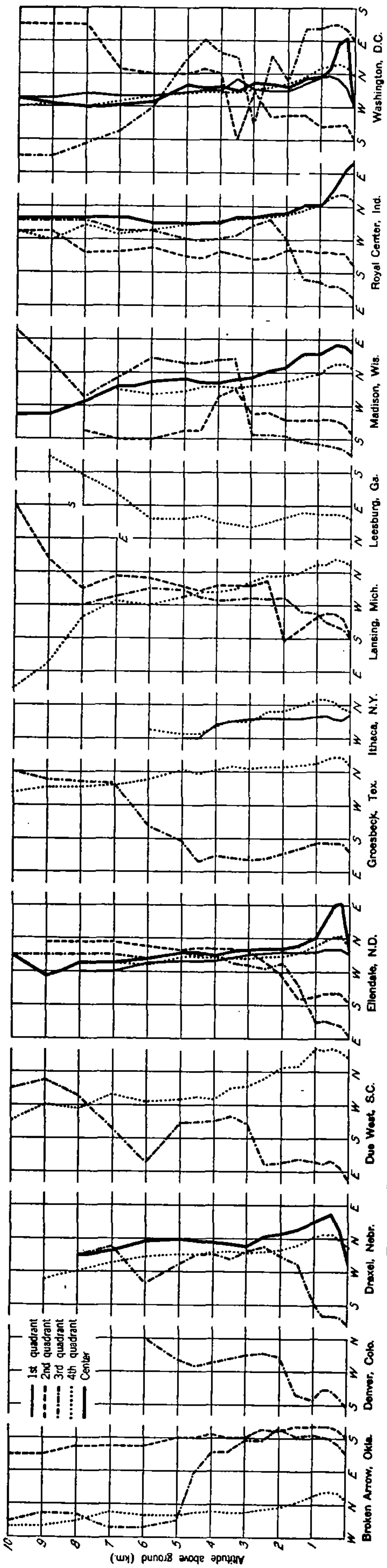


FIG. 18.—Mean wind directions determined from pilot-balloon observations in various quadrants of well pronounced HIGHS during summer

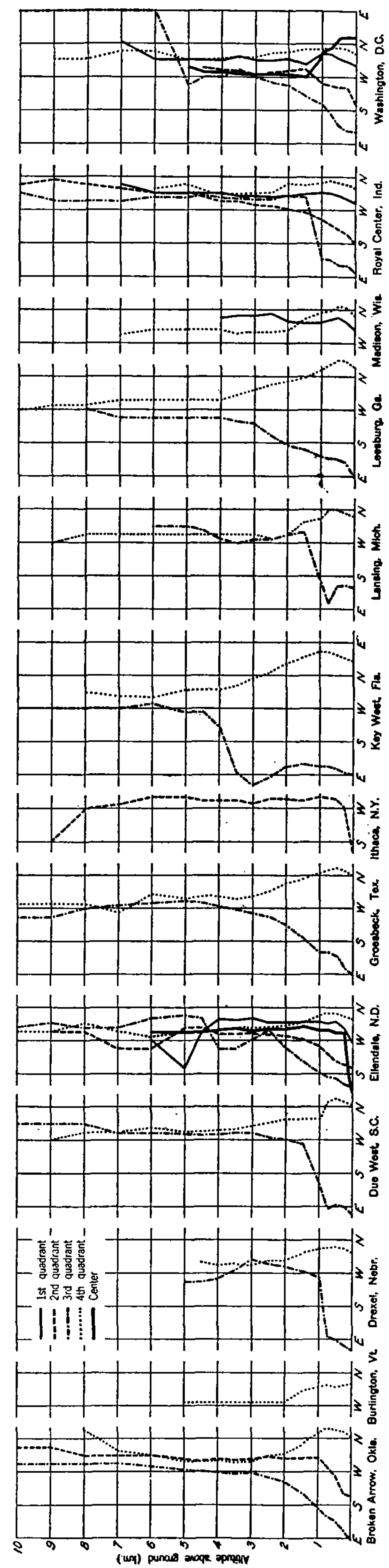


FIG. 20.—Mean wind directions from pilot-balloon observations in winter HIGHS

Notwithstanding these differences in method the primary distinguishing characteristics of HIGHS and LOWS by quadrants and seasons were approximately the same for both countries.

The mean wind velocities of HIGHS and LOWS at Lindenburg were less than for all but the southernmost stations in this country.

The pronounced *decrease* in the mean wind velocities occurring just above the ground stratum at the stations in this country is practically absent in the German data wherein only a falling off or retardation in the *rate of increase* with elevation at these levels occurs.

Peppler calls attention to the fact that the vertical wind gradients of the various quadrants clearly demonstrate the unsymmetrical structure of HIGHS and LOWS. This is likewise well brought out in the present paper in the graphs for winds as well as for the other elements.

WIND DIRECTION

The mean wind direction determined from pilot-balloon and kite observations in various quadrants of HIGHS and LOWS for summer and winter are shown in figures 18 to 25, inclusive.

Mean wind directions are determined independently of velocity and therefore do not necessarily bear a relationship to the mean values of the latter. Moreover, it is not feasible in determining mean wind directions to weight the observations of the higher levels by the more numerous ones of the lower levels as is customarily done in the case of the scalar quantities, viz, wind velocity, temperature, etc. It is evident therefore that a greater number of observations is necessary for determining reliable mean wind directions than for obtaining mean wind velocities. The values here given however are believed reliable for the most part except in some cases at the higher levels where occasionally marked irregularities in the direction graphs occur.

It is found that there is a generally greater divergence at the upper ends of the wind direction curves representing kite observations than at the corresponding levels of those representing pilot balloon observations. This is due to the fact that when the wind makes an abrupt shift the balloon immediately adjusts itself to the new direction, whereas more time is required for the kite and, in fact, the latter is frequently unable to rise into the upper current. We conclude, therefore, that the mean wind directions indicated by pilot-balloon

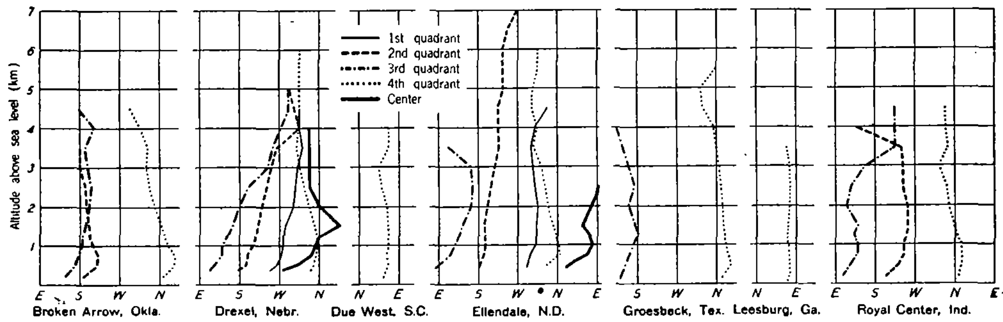


FIG. 19.—Mean wind directions from kite observations in summer HIGHS

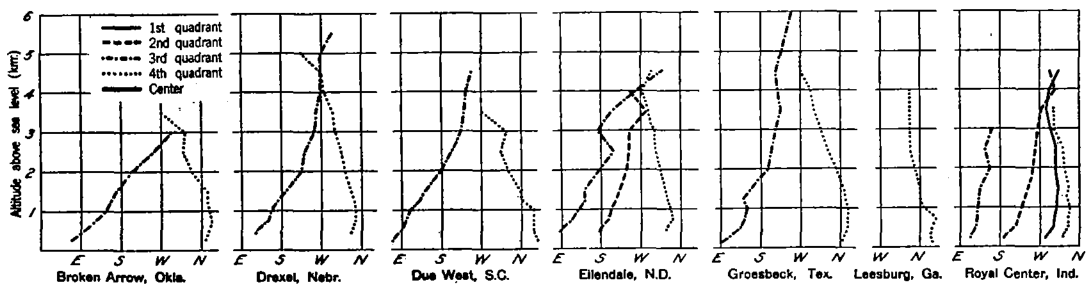


FIG. 21.—Mean wind directions from kite observations in winter HIGHS

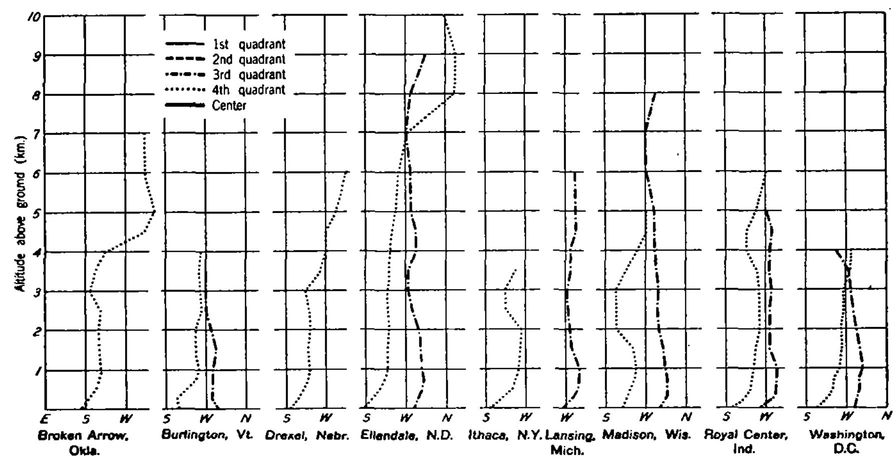


FIG. 22.—Mean wind directions from pilot-balloon observations in summer LOWS

observations are more truly representative than are those obtained with kites.

The ground stratum in HIGHS and LOWS, i. e., the first few hundred meters wherein a marked increase in the mean wind velocity was noted, is found to contain a pronounced *veering* of the wind with altitude. This shift with elevation is greatest in those quadrants con-

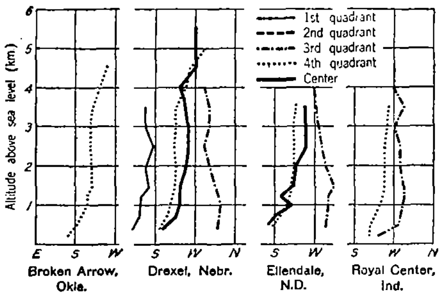


FIG. 23.—Mean wind directions from kite observations in summer LOWS

taining southerly winds, i. e., in the rear sector of HIGHS and front sector of LOWS. This is in agreement with results obtained by W. R. Gregg (*2*) when the average turning of the wind with altitude was determined for each surface wind direction. Gregg shows that the veering in this ground stratum is considerably more pronounced with southerly winds than with northerly.

There is practically no difference between HIGHS and LOWS in regard to the degree of this wind shift throughout the ground stratum.

The front sector of HIGHS is found to be the region of least change in wind direction with elevation. A nearly constant mean direction, extending from a short distance above ground to the highest altitudes indicated, is found in this sector at practically all stations.

The third quadrant of HIGHS contains the maximum shift in the mean wind direction with altitude, changing

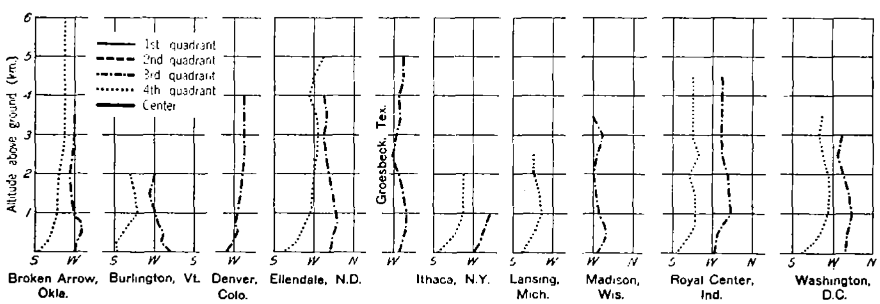


FIG. 24.—Mean wind directions from pilot-balloon observations in winter LOWS

from a pronounced southerly to an equally marked northerly direction at practically all stations. The mean height of this shift is found, in general, to vary inversely with latitude, being highest at Key West, but at all stations it is lower in winter than in summer. At some of the stations this transition is indicated in the means by an abrupt shift while at others it is more or less gradual.

The mean wind directions in HIGHS at Ellendale, the northernmost station, are practically the same above 2 km., for all quadrants including the central region. In general, a common mean wind direction in all quadrants of HIGHS at any station is reached at successively greater heights from northern to southern stations.

Free air data for the first and second quadrants of LOWS are comparatively meager, but from those available it is evident that a marked difference in the mean wind direction between these two quadrants persists to at least 4 km. The first quadrant maintains a large south component, while the second quadrant has an equally pronounced north component to this height. (See fig. 25.)

It is evident that a common mean wind direction, containing a large west component, obtains in the upper levels of the third and fourth quadrants of LOWS commencing at a height varying at the different stations from 2 to 3 km. in winter and from 3 to 5 km. in summer. At the northern stations this mean direction is slightly north of west, whereas, at the southern stations, a small south component is evident.

The mean wind direction for the center of LOWS is practically southwest and merges at about 4 km. with that for the third and fourth quadrants. This south-

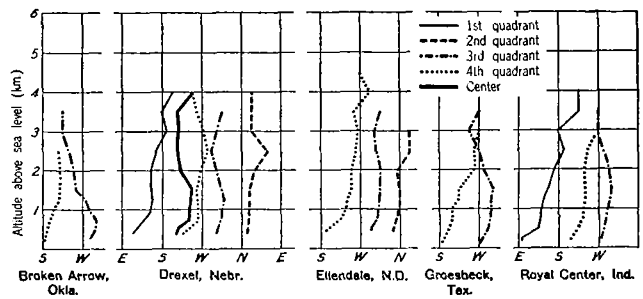


FIG. 25.—Mean wind directions from kite observations in winter LOWS

westerly current over the center of LOWS, *as they appear at the surface*, is evidently related to the frequent westward displacement of their centers aloft, whereas the northwesterly current over the centers of HIGHS is likewise associated with a similar displacement of their centers aloft. Thus it is rather strikingly shown that *above* the warm sectors of both HIGHS and LOWS, *as they appear at the surface*, the pressure is relatively high while above their cold sectors it is relatively low, thereby producing gradients aloft in accordance with the mean wind directions found.

TEMPERATURE

The mean vertical temperature distribution for various quadrants of HIGHS and LOWS for summer and winter are shown in Figures 26 to 29, inclusive.

As might be expected in a classification of well-pronounced pressure areas there occur marked differences in characteristics between the average lapse rate curves, particularly between those representing HIGHS as compared with LOWS. Differences between the respective front and rear sectors of each pressure system as well as marked seasonal diversities are likewise evident. In general these differences are more pronounced at the northern stations than at the southern, although certain variations occur in the curves for individual stations. The numerous details presented in the various graphs and tables prohibit reference to all in this discussion.

The principal characteristics of the average lapse rate curves are probably best ascertained by comparing these for adjacent sectors of both pressure systems, i. e., the front sector of HIGHS with the rear sector of LOWS, and vice versa. In this way the wind streams (in the lower levels) are of the same general direction, viz, northerly in the one case and southerly in the other.

A comparison of the average *positive* lapse rate characteristic of the ground stratum in the front sector of HIGHS and rear sector of LOWS with the average *negative* lapse rate found in the lower stratum of the front sector of LOWS and rear sector of HIGHS strikingly brings out

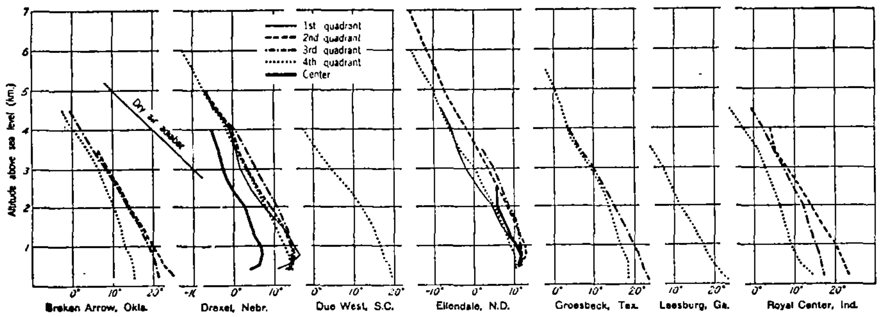


FIG. 26.—Mean temperatures, °C., for various heights as determined from kite observations in various quadrants of well-pronounced HIGHS during summer

the intimate connection between the average vertical temperature gradients and the wind directions found in these respective regions. In a study of free air temperatures in relation to wind direction (without reference to pressure distribution) W. R. Gregg (3) showed that the average lapse rate throughout the first 500 m., is *greatest* with *northerly* winds and *least* with *southerly*. Discussing the cause of this relationship he states:

> Southerly winds are, of course, cooled at the surface as they move to higher latitudes; this cooling produces a stable condition of the air and therefore does not extend to the upper levels. Northerly winds, on the other hand, are warmed at the surface in their progress toward lower latitudes, and this warming *does* extend to the upper levels, in diminished degree, of course, since it tends to a condition of instability and therefore convectional activity sets in.

There will be noted in the curves representing the front sector of HIGHS and the rear sector of LOWS, particularly for winter, three distinct strata, viz, a ground layer extending upward a few hundred meters which contains a conspicuous decrease in the mean temperature with altitude; an "average inversion layer" [3] superimposed upon the ground stratum, extending upward for several hundred meters, and above this, a steady decrease in the mean temperature with elevation to the upper limits of observation.

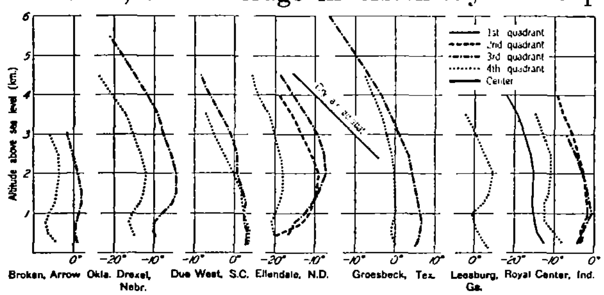


FIG. 27.—Mean temperatures, °C., from kite observations in winter HIGHS

The chief characteristics indicated by the curves representing the rear sector of HIGHS and the front sector of LOWS (i. e., the regions containing southerly winds in their lower levels) are an average inversion layer extending from the ground to several hundred meters above, following which there occurs a relatively marked decrease in the mean temperature with height which continues to the upper limits of observation.

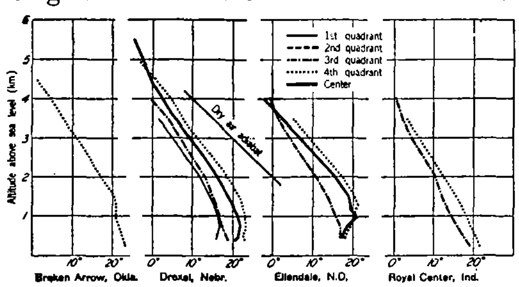


FIG. 28.—Mean temperatures, °C., from kite observations in summer LOWS

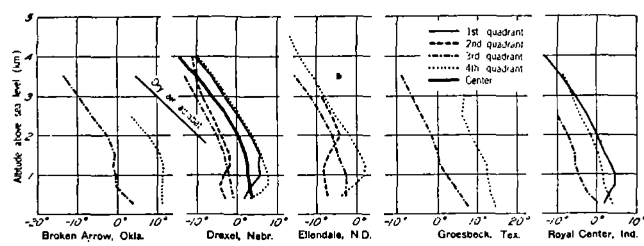


FIG. 29.—Mean temperatures, °C., from kite observations in winter LOWS

In the present examination of data (for well-marked pressure distributions) we find an intensification of these vertical temperature gradients. In the front sector of HIGHS and rear sector of LOWS there accordingly occur, extending directly off the ground, a *positive* average lapse rate caused by the northerly winds being warmed at the surface, while in the front sector of LOWS and rear sector of HIGHS a *negative* average lapse rate is found caused by the southerly winds being cooled at the surface. (See figs. 27 and 29.)

Furthermore, a pronounced latitudinal effect is evident in the increasing thickness of this ground stratum for winter HIGHS, ranging from about 300 m. at Ellendale, to about 900 m. at Leesburg.

The average inversion layer found superimposed upon this ground stratum, in the case of northerly winds, is a phenomenon usually associated with pronounced high-pressure areas particularly in winter and is evidence of the high degree of stability occurring under these conditions. It is frequently found that the wind direction indicates an appreciably *different* trajectory of the air in this stratum as compared to that of the relatively colder air beneath.

The average vertical temperature gradients in HIGHS and LOWS for summer and winter are shown in Tables 2 to 5, inclusive.

[3] The term "average inversion layer" as here used must not be construed as necessarily meaning the average of a series of observations, *all* of which indicated inversions, but, instead, the net result of a series which indicated both inversions and noninversions. It has been suggested by Dr. B. M. Varney that the term "statistical" might appropriately be used to designate any such results as the lapse rates here considered, in which the observations are combined to form an "inversion," which is such because in the statistical result the inversions outweigh the noninversions. The statistical inversion is thus the same sort of useful fiction as the "statistical cyclone" which British meteorologists have recently employed to designate such cyclones as, for instance, the Iceland LOW, which appears on our annual charts in the guise of reality because the traveling low pressure areas which pass through that region considerably outweigh in frequency or intensity or both the high pressure areas.

TABLE 2.—*Mean vertical temperature gradients, °C., per 100 m., in various quadrants of well-pronounced "highs" during summer*

Height (m.) M. S. L.	II Q.	III Q.	IV Q.	I Q.	II Q.	III Q.	IV Q.	Center	IV Q.	I Q.	II Q.	III Q.	IV Q.	Center	III Q.	IV Q.	IV Q.	II Q.	III Q.	IV Q.
6,500–7,000											0.46									
6,000–6,500											0.44									
5,500–6,000							0.58				0.44		0.56							
5,000–5,500							0.54				0.44		0.56			0.40				
4,500–5,000					0.70	0.44	0.56				0.56		0.48			0.44				
4,000–4,500		0.52	0.58	0.60	0.64	1.00	0.54			0.48	0.58		0.44			0.24			0.56	0.70
3,500–4,000		0.60	0.68	0.32	0.34	0.58	0.48	0.28	0.70	0.32	0.52		0.48		0.60	0.62		0.16	0.54	0.70
3,000–3,500	0.48	0.64	0.54	0.18	0.40	0.50	0.50	0.24	0.68	0.36	0.52	0.56	0.72		0.60	0.60	0.60	0.60	0.50	0.40
2,500–3,000	0.58	0.62	0.36	0.50	0.56	0.46	0.50	0.44	0.78	0.58	0.50	0.38	0.48		0.50	0.46	0.38	0.64	0.40	0.40
2,000–2,500	0.46	0.48	0.38	0.68	0.58	0.50	0.44	0.44	0.66	0.72	0.44	0.34	0.48	−0.06	0.48	0.34	0.48	0.54	0.52	0.30
1,500–2,000	0.60	0.54	0.30	0.74	0.56	0.40	0.42	0.28	0.58	0.44	0.44	0.38	0.42	0.34	0.52	0.28	0.60	0.56	0.24	0.22
1,250–1,500	0.60	0.48	0.24	0.80	0.52	0.36	0.48	0.48	0.44	0.64	0.44	0.24	0.36	0.60	0.48	0.28	0.56	0.68	0.32	0.20
1,000–1,250	0.52	0.44	0.24	0.60	0.40	0.20	0.44	0.68	0.44	0.72	0.44	0.24	0.44	0.60	0.48	0.40	0.64	0.60	0.40	0.40
750–1,000	0.52	0.40	0.48	0.56	0.32	0.16	0.44	0.08	0.32	0.56	0.12	0.16	0.28	0.64	0.44	0.44	0.36	0.48	0.40	0.40
500–750	0.56	0.24	0.32	−1.08	−0.32	−0.20	0.24	−0.20	0.52	0.12	−0.60	−0.16	0.00	−0.28	0.44	0.36	0.60	0.40	0.20	0.60
250–500	0.80	0.16	0.08	−2.88	−0.96	−0.19	0.00	−2.02	0.24	−0.93	−0.72	−0.72	0.18	−0.18	0.36	0.00	0.76	0.44	0.16	1.00
Surface–250	0.59	0.00	0.00						0.61						0.37	−0.09	1.15	0.40	0.40	1.20
	Broken Arrow, Okla.			Drexel, Nebr.					Due West, S. C.	Ellendale, N. Dak.					Groesbeck, Tex.		Leesburg, Ga.	Royal Center, Ind.		

TABLE 3.—*Mean vertical temperature gradients, °C., per 100 m., in various quadrants of well-pronounced "highs" during winter*

Height (m.) M. S. L.	III Q.	IV Q.	III Q.	IV Q.	III Q.	IV Q.	II Q.	III Q.	IV Q.	III Q.	IV Q.	IV Q.	I Q.	II Q.	III Q.	IV Q.
5500–6000										0.68						
5000–5500			0.68							0.68						
4500–5000			0.56							0.62						
4000–4500			0.66	0.68	0.46			0.66	0.28	0.56	0.38					
3500–4000			0.46	0.60	0.56		0.62	0.56	0.50	0.44	0.40		0.52	0.24		
3000–3500			0.34	0.44	0.54	0.36	0.52	0.66	0.34	0.48	0.32	0.56	0.42	0.52		0.44
2500–3000	0.26	0.40	0.34	0.40	0.24	0.48	0.52	0.32	0.18	0.46	0.24	0.48	0.28	0.28	0.40	0.38
2000–2500	0.26	0.06	0.24	0.26	0.02	0.54	0.36	0.06	0.18	0.22	0.14	0.44	0.18	0.28	0.36	0.04
1500–2000	0.18	−0.12	0.00	−0.14	0.26	0.34	−0.10	−0.34	−0.06	0.20	0.06	−0.18	−0.04	0.08	0.28	−0.10
1250–1500	−0.04	−0.24	−0.36	−0.44	0.24	0.12	−0.20	−0.56	−0.24	0.24	0.08	−0.68	−0.12	0.16	0.12	−0.44
1000–1250	−0.28	−0.64	−1.04	−0.72	−0.12	0.16	−0.48	−0.80	−0.36	0.12	−0.08	−1.00	0.16	0.04	0.08	−0.04
750–1000	−0.28	−0.36	−0.68	−0.36	0.04	0.24	−0.80	−1.04	−0.32	0.08	−0.24	0.04	0.12	−0.36	−0.40	0.12
500–750	−0.12	0.28	−0.04	0.36	0.16	0.20	−2.08	−0.64	0.16	−0.12	−0.24	0.36	0.28	−0.36	−0.52	0.64
250–500	0.20	0.84	0.19	0.58	−0.08	−0.04	−2.14	−0.54	0.18	−0.28	0.28	0.64	0.52	0.00	−0.32	0.92
Surface—250	0.59	0.59			0.00	−0.30				−0.46	0.46	0.79	0.80	0.00	−0.80	0.80
	Broken Arrow, Okla.		Drexel, Nebr.		Due West, S. C.		Ellendale, N. Dak.			Groesbeck, Tex.		Leesburg, Ga.	Royal Center, Ind.			

TABLE 4.—*Mean vertical temperature gradients, °C., per 100 m., in various quadrants of well-pronounced "lows" during summer*

Height (m.) M. S. L.	IV Q.	I Q.	III Q.	IV Q.	Center	III Q.	IV Q.	Center	III Q.	IV Q.
5000–5500					0.42					
4500–5000				0.76	0.48					
4000–4500	0.68			0.80	0.56					
3500–4000	0.66		0.82	0.64	0.66	0.40		0.90	0.32	
3000–3500	0.64	0.68	0.60	0.70	0.72	0.58	0.82	0.88	0.54	0.60
2500–3000	0.64	0.76	0.60	0.76	0.72	0.60	0.82	0.88	0.56	0.58
2000–2500	0.60	0.62	0.60	0.72	0.68	0.66	0.80	0.88	0.52	0.58
1500–2000	0.62	0.46	0.36	0.50	0.52	0.56	0.56	0.60	0.34	0.58
1250–1500	0.20	0.56	0.44	0.36	0.48	0.52	0.32	0.36	0.40	0.60
1000–1250	0.00	0.40	0.40	0.32	0.40	0.40	−0.16	0.52	0.60	0.56
750–1000	0.24	0.16	0.16	0.08	0.28	0.48	−0.40	−0.68	0.56	0.40
500–750	0.36	−0.32	0.48	−0.28	−0.28	0.00	−0.48	−0.64	0.56	0.36
250–500	0.28	−0.19	0.38	0.29	−0.58	−0.18	−0.36	−0.71	0.76	0.52
Surface–250	0.58								0.80	0.40
	Broken Arrow, Okla.	Drexel, Nebr.				Ellendale, N. Dak.			Royal Center, Ind.	

TABLE 5.—*Mean vertical temperature gradients, °C., per 100 m., in various quadrants of well-pronounced "lows" during winter*

Heights (m.) M. S. L.	III Q.	IV Q.	I Q.	II Q.	III Q.	IV Q.	Center	II Q.	III Q.	IV Q.	III Q.	IV Q.	I Q.	III Q.	IV Q.
4,000–4,500										0.50					
3,500–4,000			0.84	0.16		0.80	0.90			0.62			0.74		
3,000–3,500	0.70		0.66	0.30	0.56	0.72	0.78		0.74	0.64	0.52		0.80		0.40
2,500–3,000	0.70		0.66	0.52	0.54	0.60	0.82	0.50	0.64	0.56	0.52	−0.10	0.62		0.44
2,000–2,500	0.78	0.84	0.60	0.44	0.52	0.56	0.48	0.40	0.52	0.66	0.52	0.38	0.44	0.58	0.48
1,500–2,000	0.34	0.60	0.46	0.40	0.38	0.44	0.36	−0.52	0.26	0.56	0.22	0.52	0.38	0.36	0.42
1,250–1,500	−0.12	0.32	−0.08	0.04	0.20	0.52	0.28	−0.48	0.36	0.48	0.20	0.52	0.48	0.04	0.20
1,000–1,250	0.24	−0.12	0.12	−0.60	0.24	0.28	−0.04	0.00	0.48	−0.12	0.60	0.08	0.48	0.32	0.24
750–1,000	−0.08	0.04	−0.72	−0.32	0.28	0.00	0.28	0.20	−0.04	−0.80	0.76	0.12	−0.04	0.40	0.04
500–750	0.80	0.08	−0.68	0.32	0.12	−1.00	0.16	0.12	0.00	−1.24	0.72	0.32	−0.48	0.64	0.40
250–500	1.00	−0.12	−0.48	0.48	0.19	−1.83	0.29	0.54	0.00	−1.07	0.64	0.32	−0.36	0.84	0.52
Surface–250	1.18	0.00									0.55	0.27	−0.40	0.80	0.40
	Broken Arrow, Okla.		Drexel, Nebr.					Ellendale, N. Dak.			Groesbeck, Tex.		Royal Center, Ind.		

A marked decrease in the average lapse rates in both HIGHS and LOWS, especially in the former, is found in winter as compared with summer.

The average lapse rates of the upper levels of LOWS are greater than those for the same levels of HIGHS for the same seasons, particularly for winter. This indicates rather strikingly the comparatively steeper lapse rates occurring during conditions most favorable for precipitation.

The mean temperatures in HIGHS and LOWS for summer and winter are shown in Tables 6 to 9, inclusive.

TABLE 6.—*Mean temperatures, °C., in various quadrants of well-pronounced "highs" during summer*

Height (m.) M. S. L.	Broken Arrow, Okla.			Drexel, Nebr.					Due West, S. C.	Ellendale, N. Dak.					Groesbeck, Tex.		Leesburg, Ga.	Royal Center, Ind.		
	II. Q.	III Q.	IV Q.	I Q.	II Q.	III Q.	IV Q.	Center	IV Q.	I Q.	II Q.	III Q.	IV Q.	Center	III Q.	IV Q.	IV Q.	II Q.	III Q.	IV Q.
7,000											−16.1									
6,500											−13.8									
6,000							−12.7				−11.6		−15.8							
5,500							−9.8				−9.4		−13.0			−1.9				
5,000					−7.0	−6.7	−7.1				−7.2		−10.2			0.1				
4,500		−0.4	−2.5	−3.9	−3.5	−4.5	−4.3			−7.6	−4.4		−7.8			2.3			−0.4	−6.0
4,000		2.2	0.4	−0.9	−0.3	0.5	−1.6	−5.2	−2.7	−5.2	−1.5		−5.6		3.8	3.5		4.3	2.4	−2.5
3,500	6.4	5.2	3.8	0.7	1.4	3.4	0.8	−3.8	0.8	−3.6	1.1	2.3	−3.2		6.8	6.6	4.2	5.1	5.1	1.0
3,000	8.8	8.4	6.5	1.6	3.4	5.9	3.3	−2.6	4.2	−1.8	3.7	5.1	0.4		9.8	9.6	7.2	8.1	7.6	3.0
2,500	11.7	11.5	8.3	4.1	6.2	8.2	5.8	−0.4	8.1	1.1	6.2	7.0	2.8	6.0	12.3	11.9	9.1	11.3	9.6	5.0
2,000	14.0	13.9	10.2	7.5	9.1	10.7	8.0	2.6	11.4	4.7	8.4	8.7	5.2	5.7	14.7	13.6	11.5	14.0	12.3	6.5
1,500	17.0	16.6	11.7	11.2	11.9	12.7	10.1	4.0	14.3	6.9	10.6	10.6	7.3	7.4	17.3	15.0	14.5	16.8	13.5	7.6
1,250	18.5	17.8	12.3	13.2	13.2	13.6	11.3	5.2	15.4	8.5	11.7	11.2	8.2	8.9	18.5	15.7	15.9	18.5	14.3	8.1
1,000	19.8	18.9	12.9	14.7	14.2	14.1	12.4	6.9	16.5	10.3	12.8	11.8	9.3	10.4	19.7	16.7	17.5	20.0	15.3	9.1
750	21.1	19.9	14.1	16.1	15.0	14.5	13.5	7.1	17.3	11.7	13.1	12.2	10.0	12.0	20.8	17.8	18.4	21.2	16.3	10.1
500	22.5	20.5	14.9	13.4	14.2	14.0	14.1	6.1	18.6	12.0	11.6	11.8	10.0	11.3	21.9	18.7	19.9	22.2	16.8	11.6
250	24.5	20.9	15.1						19.2						22.8	18.7	21.8	23.3	17.2	14.1
Surface	24.6	20.9	15.1	10.4	13.2	13.8	14.1	4.0	19.4	11.5	11.2	11.4	10.1	11.2	23.2	18.6	23.7	23.4	17.3	14.4

TABLE 7.—*Mean temperatures, ° C., in various quadrants of well-pronounced "highs" during winter*

Height (m.) M. S. L.	Broken Arrow, Okla.		Drexel, Nebr.		Due West, S. C.		Ellendale, N. Dak.			Groesbeck, Tex.		Leesburg, Ga.	Royal Center, Ind.			
	III Q.	IV Q.	III Q.	IV Q.	III Q.	IV Q.	II Q.	III Q.	IV Q.	III Q.	IV Q.	IV Q.	I Q.	II Q.	III Q.	IV Q.
6,000										−16.5						
5,500			−21.2							−13.1						
5,000			−17.8							−9.7						
4,500			−15.0	−23.9	−8.4			−18.8	−25.7	−6.6	−7.7					
4,000			−11.7	−20.5	−6.1		−19.3	−15.5	−24.3	−3.8	−5.8		−22.0	−9.1		
3,500			−9.4	−17.5	−3.3	−7.1	−16.2	−12.7	−21.8	−1.6	−3.8	−2.7	−19.4	−7.9		−14.9
3,000	−1.6	−6.0	−7.7	−15.3	−0.6	−5.3	−13.6	−9.4	−20.1	0.8	−2.2	0.1	−17.3	−5.3	−6.6	−12.7
2,500	−0.3	−4.0	−6.0	−13.3	0.6	−2.9	−11.0	−7.8	−19.2	3.1	−1.0	2.5	−15.9	−3.9	−4.6	−10.8
2,000	1.0	−3.7	−4.8	−12.0	0.7	−0.2	−9.2	−7.5	−18.3	4.2	−0.3	4.7	−15.0	−2.5	−2.8	−10.6
1,500	1.9	−4.3	−4.8	−12.7	2.0	1.5	−9.7	−9.2	−18.6	5.2	0.0	3.8	−15.2	−2.1	−1.4	−11.1
1,250	1.8	−4.9	−5.7	−13.8	2.6	1.8	−10.2	−10.6	−19.2	5.8	0.2	2.1	−15.5	−1.7	−1.1	−12.2
1,000	1.1	−6.5	−8.3	−15.6	2.3	2.2	−11.4	−12.6	−20.1	6.1	0.0	−0.4	−15.1	−1.6	−0.9	−12.3
750	0.4	−7.4	−10.0	−16.5	2.4	2.8	−13.4	−15.2	−20.9	6.3	−0.6	−0.3	−14.8	−2.5	−1.9	−12.0
500	0.1	−6.7	−10.1	−15.6	2.8	3.3	−18.6	−16.8	−20.5	6.0	−1.2	0.6	−14.1	−3.4	−3.2	−10.4
250	0.6	−4.6			2.6	3.2				5.3	−0.5	2.2	−12.8	−3.4	−4.0	−8.1
Surface	0.7	−4.5	−9.9	−15.0	2.6	3.1	−19.8	−17.1	−20.4	4.8	0.0	3.5	−12.6	−3.4	−4.2	−7.9

TABLE 8.—*Mean temperatures, ° C., in various quadrants of well-pronounced "lows" during summer*

Height (m.) M. S. L.	Broken Arrow, Okla.	Drexel, Nebr.				Ellendale, N. Dak.			Royal Center, Ind.	
	IV Q.	I Q.	III Q.	IV Q.	Center	III Q.	IV Q.	Center	III Q.	IV Q.
5,500					−4.9					
5,000				−3.1	−2.8					
4,500	1.1			0.7	−0.4					
4,000	4.5		−0.1	4.7	2.4	−0.6		−2.0	0.6	
3,500	7.8	1.6	4.0	7.9	5.7	1.4	5.1	2.5	2.2	3.7
3,000	11.0	5.0	7.0	11.4	9.3	4.3	9.2	6.9	4.9	6.7
2,500	14.2	8.8	10.0	15.2	12.9	7.3	13.3	11.3	7.7	9.6
2,000	17.2	11.9	13.0	18.8	16.3	10.6	17.3	15.7	10.3	12.5
1,500	20.3	14.2	14.8	21.3	18.9	13.4	20.1	18.7	12.0	15.4
1,250	20.8	15.6	15.9	22.2	20.1	14.7	20.9	19.6	13.0	16.9
1,000	20.8	16.6	16.9	23.0	21.1	15.7	20.5	20.9	14.5	18.3
750	21.4	17.0	17.3	23.2	21.8	16.9	19.5	19.2	15.9	19.3
500	22.3	16.2	18.5	22.5	21.1	16.9	18.3	17.6	17.3	20.2
250	23.0								19.2	21.5
Surface	23.1	16.0	18.9	22.8	20.5	16.8	18.1	17.2	19.4	21.6

TABLE 9.—*Mean temperatures, °C., in various quadrants of well-pronounced "lows" during winter*

Height (m.) M. S. L.	Broken Arrow, Okla.		Drexel, Nebr.					Ellendale, N. Dak.			Groesbeck, Tex.		Royal Center, Ind.		
	III Q.	IV Q.	I Q.	II Q.	III Q.	IV Q.	Center	II Q.	III Q.	IV Q.	III Q.	IV Q.	I Q.	III Q.	IV Q.
4,500										−16.9					
4,000			−10.5	−11.1		−9.9	−14.7			−14.4			−13.0		
3,500	−13.4		−6.5	−10.3	−13.1	−5.9	−10.2		−15.6	−11.3	−8.9		−9.3		−8.3
3,000	−9.9		−3.0	−8.8	−10.3	−2.3	−6.3	−8.9	−11.9	−8.1	−6.3	6.9	−5.3		−6.3
2,500	−6.4	3.3	0.3	−6.2	−7.6	0.7	−2.2	−6.4	−8.7	−5.3	−3.7	6.4	−2.2	−10.2	−4.1
2,000	−2.5	7.5	3.3	−4.0	−5.0	3.5	0.2	−4.4	−6.1	−2.0	−1.1	8.3	0.0	−7.3	−1.7
1,500	−0.8	10.5	5.6	−2.0	−3.1	5.7	2.0	−7.0	−4.8	0.8	0.0	10.9	1.9	−5.5	0.4
1,250	−1.1	11.3	5.4	−1.9	−2.6	7.0	2.4	−8.2	−3.9	2.0	0.5	12.2	3.1	−5.4	0.9
1,000	−0.5	11.0	5.7	−3.4	−2.0	7.7	2.3	−8.2	−2.7	1.7	2.0	12.4	4.3	−4.6	1.5
750	−0.7	11.1	3.9	−4.2	−1.3	7.7	3.0	−7.7	−2.8	−0.3	3.9	12.7	4.2	−3.6	1.6
500	1.3	11.3	2.2	−3.4	−1.0	5.2	3.4	−7.4	−2.8	−3.4	5.7	13.5	3.0	−2.0	2.6
250	3.8	11.0									7.3	14.3	2.1	0.1	3.9
Surface	4.0	11.0	1.7	−2.9	−0.8	3.3	3.7	−7.1	−2.8	−4.0	7.9	14.6	2.0	0.3	4.0

An examination of these tables shows that the seasonal differences in the mean temperatures are greater for HIGHS than for LOWS and greater in the lower levels than in the upper of *both* pressure systems.

The average lapse rates between the ground and 3 km. above sea level in HIGHS and LOWS for summer and winter are shown in Table 10.

TABLE 10.—*Average temperature lapse rates °C. per 100 m., for the air column between the ground and 3,000 m. (sea level) for various quadrants of well-pronounced "highs" and "lows" for summer and winter*

HIGHS

	Summer					Winter				
	1 Q.	2 Q.	3 Q.	4 Q.	Center	1 Q.	2 Q.	3 Q.	4 Q.	Center
Broken Arrow, Okla		0.57	0.45	0.31				0.08	0.05	
Drexel, Nebr	0.34	0.38	0.30	0.42	0.25			−0.08	0.01	
Due West, S. C				0.55				0.11	0.30	
Ellendale, N. Dak	0.52	0.29	0.25	0.38	0.28		−0.24	−0.30	−0.01	
Groesbeck, Tex			0.47	0.31				0.14	0.08	
Leesburg, Ga				0.57					0.12	
Royal Center, Ind		0.55	0.35	0.41		0.17	0.07	0.09	0.17	
Mount Weather, Va	0.49	0.59	0.55	0.55		0.27	0.22	0.05	0.28	

LOWS

	Summer					Winter				
	1 Q.	2 Q.	3 Q.	4 Q.	Center	1 Q.	2 Q.	3 Q.	4 Q.	Center
Broken Arrow, Okla				0.44				0.50	0.43	
Drexel, Nebr	0.42		0.46	0.44	0.43	0.18	0.23	0.36	0.22	0.38
Due West, S. C										
Ellendale, N. Dak			0.49	0.35	0.40		0.07	0.36	0.16	
Groesbeck, Tex								0.50	0.27	
Leesburg, Ga										
Royal Center, Ind			0.52	0.57		0.26		0.49	0.37	
Mount Weather, Va	0.50	0.62	0.61	0.60		0.28	0.34	0.53	0.36	

There have included in this table corresponding values obtained by Blair (*4*) for Mount Weather, Va., which it will be noted are appreciably higher than are those found in the present study. This is partly because the temperature results of the Mount Weather data are based on the *means* of the ascents and descents of kite flights and therefore on higher temperatures, especially for the lower levels, than would have been the case had the ascents only been used as was done for the other stations and partly owing to the fact that the present paper represents primarily the more pronounced pressure types.

Table 10 contains the following significant features:

The average lapse rates to 3 km. are greater in LOWS than in adjacent sectors of HIGHS both for summer and winter, the differences between the two pressure types being most pronounced in winter.

The average lapse rates are greater at the southern stations than at the northern in HIGHS and in LOWS in both seasons.

The average lapse rates are appreciably less in winter than in summer in both HIGHS and LOWS, the seasonal differences being most marked in HIGHS.

The average lapse rates are greater in the front sector of HIGHS than in their rear at the *northern* stations in both seasons, whereas the opposite relationship obtains at the *southern* stations.

The average lapse rates are greater in the rear sector of LOWS than in their front in both seasons at both northern and southern stations.

The pronounced temperature inversions extending to great elevations characteristic of winter HIGHS, especially at the northern stations, are strikingly shown in the average *negative* lapse rates for both their front and rear sectors at Ellendale and in the smallness of the positive values at the other stations.

A comparison was made of the temperature results obtained for Drexel in this study with those found for the same station by Gregg (*5*) in an earlier paper. Although the latter was necessarily based on a shorter record which made it impossible to restrict the pressure types to well pronounced cases, a close agreement was found between the mean temperatures for the upper levels with those found here. However, since the means of the ascents and descents of kite flights were used the values for the surface and lower levels were, as might be expected, generally higher than those found here.

TABLE 11.—*Excess or deficiency (−) of mean temperatures, °C., of (A) the rear sector (second and third quadrants) of "lows" as compared with the front sector (first and fourth quadrants) of "highs" and of (B) the front sector of "lows" as compared with the rear sector of "highs"*

SUMMER

Height (m.) M. S. L.	(A) Northerly currents			(B) Southerly currents			
	Drexel, Nebr.	Ellendale, N. Dak.	Royal Center, Ind.	Broken Arrow, Okla.	Drexel, Nebr.	Ellendale, N. Dak.	Royal Center, Ind.
5,000					2.1		
4,500		1.7		1.4	3.1		
4,000	1.8	4.5	1.7	2.2	3.3	0.9	
3,500	3.2	4.4	−0.2	2.5	4.3	3.3	−0.1
3,000	3.9	5.0	0.7	2.7	5.4	4.6	0.0
2,500	4.4	5.6	1.6	2.9	6.[illegible]	6.3	0.0
2,000	5.0	6.0	2.6	3.5	7.[illegible]	8.2	0.3
1,500	4.9	6.3	3.3	3.8	[illegible].6	9.0	1.2
1,250	4.9	6.8	3.7	3.0	[illegible].6	8.9	1.5
1,000	4.5	6.6	4.1	1.8	7.7	7.7	1.7
750	3.7	6.7	4.3	1.3	7.4	6.4	1.6
500	4.5	6.7	4.2	1.4	7.3	6.0	1.8
250			3.5	1.3			2.5
Surface	5.1	6.8	3.3	1.3	7.9	6.1	2.5

TABLE 12.—*Excess or deficiency (—) of mean temperatures, °C., of (A) the rear sector (second and third quadrants) of "lows" as compared with the front sector (first and fourth quadrants) of "highs" and of (B) the front sector of "lows" as compared with the rear sector of "highs"*

WINTER

Height (m.) M. S. L.	(A) Northerly currents						(B) Southerly currents				
	Broken Arrow, Okla.	Drexel, Nebr.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.	Broken Arrow, Okla.	Drexel, Nebr.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
4,500									3.6		
4,000		7.3						1.4	2.8		−3.7
3,500		5.4	−3.1	6.8	−5.1			2.8	4.0		−1.2
3,000	−3.7	5.5	−1.6	8.6	−4.1			4.7	3.5	6.1	−0.8
2,500	−2.2	6.3	−0.9	10.6	−2.7	3.7	4.1	6.3	4.3	3.3	0.3
2,000	1.4	7.5	−1.2	12.1	−0.8	6.1	7.0	8.0	6.5	4.1	1.1
1,500	3.7	10.1	−2.4	12.6	0.0	8.2	9.1	10.9	10.5	5.7	2.3
1,250	4.6	11.6	−1.3	13.4	0.3	9.2	9.9	12.3	12.5	6.4	2.7
1,000	6.6	13.0	−0.5	15.0	2.0	9.5	10.2	15.2	13.8	6.3	3.2
750	7.5	13.8	0.2	15.8	4.5	9.6	10.9	16.0	14.2	6.4	4.2
500	8.4	13.3	1.3	15.7	6.9	9.7	11.4	14.3	14.3	7.5	5.8
250	8.4		2.8		7.8	9.9	10.7			9.0	7.1
Surface	8.4	13.0	2.6	15.7	7.9	9.9	10.6	13.1	14.4	9.8	7.3

Considering sections (A) and (B) of Tables 11 and 12 as representing, in general, northerly and southerly winds, respectively, it is evident that in summer, LOWS average *warmer* than the adjacent sectors of HIGHS. The differences become progressively smaller, however, from northern to southern stations and from lower to higher altitudes.

In winter, at the *northern* stations, LOWS likewise average *warmer* than HIGHS, but at the *southern* and *eastern* stations they average *colder* in the *upper* levels, particularly in their rear sector as compared with the front sector of HIGHS.

European observations have shown that LOWS there average colder, above the lowest levels, than do HIGHS. In regard to this, J. Bjerknes and H. Solberg (*8*) state:

A very large percentage of European cyclones are occluded ones, being dying remainders of previously strong Atlantic depressions. The predominance of occluded cyclones in Europe has led to the statistical result that cyclones usually have a cold core. A special investigation of the relatively infrequent young deepening cyclones will certainly afford evidence of their assymetric thermal structure.

In the United States, especially in the more western parts, most cyclones *are* "young deepening cyclones" and the results in this paper evidently substantiate the final statement of the above quotation.

W. R. Gregg (*5*) in discussing the results he obtained for Drexel as contrasted to those for Europe, states:

The climate of western Europe is essentially marine in character. As such, its temperatures are subject to relatively small fluctuations due to the importation of air from adjacent localities under the influence of winds having successively a northerly and a southerly component. The proximity of the Gulf Stream tends further to a spreading out of the latitudinal isotherms, thus adding to the moderating influences of the ocean. The result is that the effects of radiation, pressure and vertical circulation are so much greater than those due to northerly or southerly winds as to produce what are actually observed, viz, lower temperatures in cyclones than in anticyclones.

The United States, on the other hand, i. e., those portions in which observations have been made, has a typically continental climate, and its temperatures are alternately affected by strong winds from a very cold northerly region and by almost equally strong winds from a very warm region. The fluctuations are large, so large indeed that they tend to mask the effects of the other factors already referred to. That these latter are operating, however, is perhaps indicated by the fact that there is less difference in the temperatures at the upper levels than at the earth's surface; more particularly is this true at Mount Weather, which lies to the south of most pronounced antcyclonic and cyclonic activity; moreover, its proximity to the Atlantic gives it to some extent a marine climate, so far as easterly and southerly winds are concerned.

Another probable contributing cause to the temperature difference in the two continents is the fact that pressure systems in Europe move only about two-thirds as rapidly as do those in the United States. In Europe, therefore, the heating and cooling effects of radiation, vertical circulation, etc., are more pronounced, since they have greater opportunity for development.

It would seem that the above explanation regarding anticyclones and that given by Bjerknes and Solberg for the "cold" cyclones found in Europe are well substantiated by the results shown in this paper.

W. Peppler (*6*) using the same observational data as that used by A. Peppler (see p. 201) has compiled the average temperature lapse rates (not actual temperatures) for 500 m. intervals for various quadrants of HIGHS and LOWS. A comparison of his results with those given in this paper showed, as in the case of the Mount Weather data, certain differences which are obviously due to the inclusion of the less pronounced pressure areas in the German study. This resulted in the latter showing wide variations in the mean vertical temperature gradients for the individual years to which fact the author frequently calls attention. Moreover, part of the differences between the two sets of data were doubtless due to the different plans followed in the methods of classifying, reference to which was previously made. Strata of maximum and minimum average lapse rates found for all quadrants of HIGHS and LOWS for each season were pointed out and in most cases the author inferred a connection between them and layers of minimum and maximum cloudiness, respectively. Too much significance, however, seems to the present writer to have been attached to exceedingly small variations in the average lapse rates obtained.

However, notwithstanding the differences in the plans followed in the two studies, it was found that in general the fundamental characteristics of the average temperature lapse rates of HIGHS and LOWS as regards distinctions for quadrants and seasons were substantially the same for both countries.

RELATIVE HUMIDITY

The mean relative humidities for various quadrants of HIGHS and LOWS for summer and winter are shown in Figures 30 to 33, inclusive.

The relatively early morning hour at which these flights were begun is responsible for the comparatively high mean relative humidities indicated for the surface, especially at the northern stations. Flights made a few hours later in the day would have resulted in the curves being practically vertical, from the ground to about 3 km.

The mean relative humidities in both HIGHS and LOWS at the *northern* stations are somewhat greater in winter than in summer. The differences become negligible, however, at the upper levels. At the *southern* stations this relationship, in the case of HIGHS, is opposite, viz, the relative humidity averages highest in summer. Insufficient observations at the southern stations prevent this seasonal comparison for LOWS. It has been shown by Gregg (*7*) that the seasonal relationship between the mean surface relative humidities at the northern and southern stations (determined *without* respect to prevailing pressure distribution) was the same as found here, viz, the relative

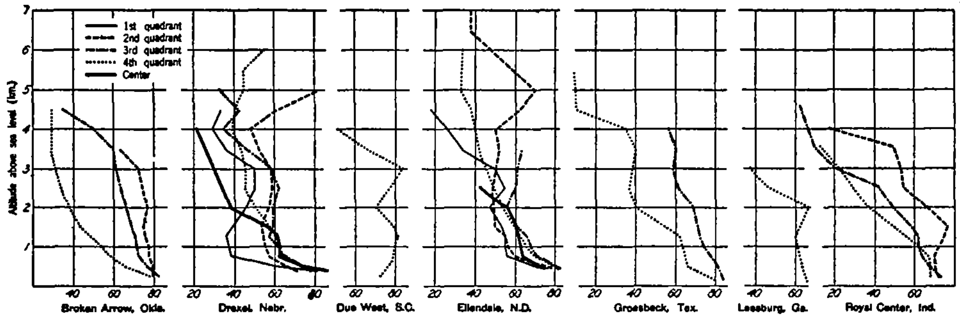


FIG. 30.—Mean relative humidities for various heights as determined from kite observations in various quadrants of well-pronounced HIGHS during summer

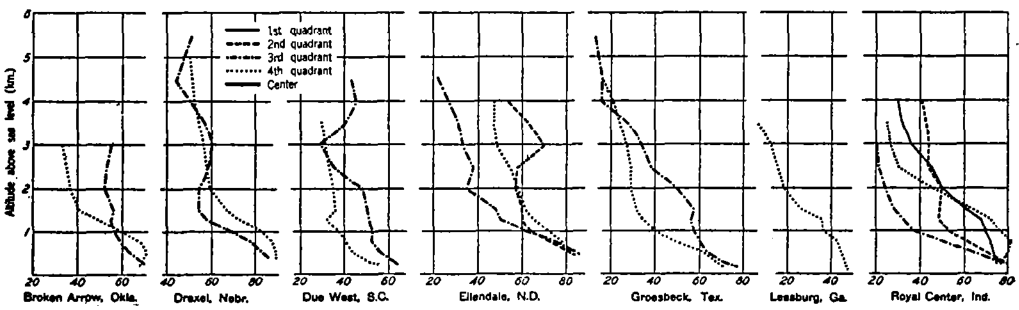


FIG. 31.—Mean relative humidities from kite observations in winter HIGHS

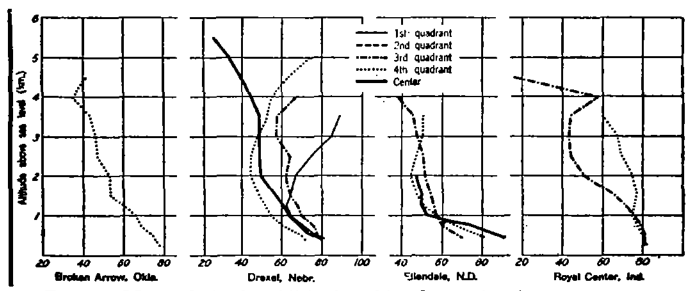


FIG. 32.—Mean relative humidities from kite observations in summer LOWS

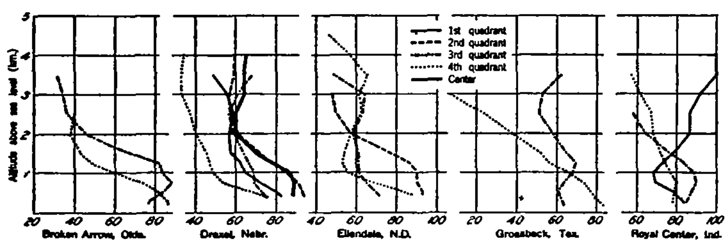


FIG. 33.—Mean relative humidities from kite observations in winter LOWS

humidity averages highest in summer at the *southern* stations and highest in winter at the *northern* stations.

A prominent feature noted in the graphs for winter HIGHS (fig. 31) is the relationship between the mean values for the third and fourth quadrants. It is evident that at Ellendale, Drexel, and Royal Center, the three northern stations, the mean relative humidity, both in the lower and upper levels averages higher in the fourth quadrant than in the third, whereas the opposite relationship occurs at the southern stations. This is, in all probability, due to the southerly winds of comparatively heavy moisture content blowing over the latter stations.

The mean relative humidity in the upper levels of the rear sector of HIGHS in summer is greater, in general, than that for their front sector, the differences being larger at the southern stations that at the northern.

The central region and fourth quadrant of HIGHS contain comparatively *low* relative humidity in their *upper* levels. From the data available it is found that the highest relative humidities in the upper levels of HIGHS occur in their second quadrant in both seasons.

TABLE 13.—*Excess or deficiency (—) of mean relative humidities (per cent) of (A) the rear sector (second and third quadrants) of "lows" as compared with the front sector (first and fourth quadrants) of "highs" and of (B) the front sector of "lows" as compared with the rear sector of "highs"*

SUMMER

Height (m.), M. S. L.	(A) Northerly currents			(B) Southerly currents			
	Drexel, Nebr.	Ellendale, N. Dak.	Royal Center, Ind.	Broken Arrow, Okla.	Drexel, Nebr.	Ellendale, N. Dak.	Royal Center, Ind.
5,000					22		
4,500		26		5	17		
4,000	29	1		−17	20	15	
3,500	13	3	44	−19	11	−6	25
3,000	9	−2	24	−18	−3	−3	29
2,500	14	−4	12	−19	−10	−3	25
2,000	12	−3	11	−15	−9	−5	21
1,500	9	−4	15	−13	−4	−6	13
1,250	7	−5	15	−11	−1	−9	10
1,000	11	−5	14	−6	−1	−4	10
750	16	−4	13	−5	1	1	11
500	8	−7	14	−2	1	1	12
250			14	−4			10
Surface	3	−8	14	−4	−2	1	9

TABLE 14.—*Excess or deficiency (−) of mean relative humidities (per cent) of (A) the rear sector (second and third quadrants) of "lows" as compared with the front sector (first and fourth quadrants) of "highs" and of (B) the front sector of "lows" as compared with the rear sector of "highs"*

WINTER

Height (m.), M. S. L.	(A) Northerly currents: Broken Arrow, Okla.	Drexel, Nebr.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.	(B) Southerly currents: Broken Arrow, Okla.	Drexel, Nebr.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
4,500									14		
4,000		16						−5	19		50
3,500		13	26	4	38			−12	21		42
3,000	10	6	22	18	26			−14	14	−27	39
2,500	10	3	21	12	22	28	−13	−10	18	−14	40
2,000	18	2	26	3	29	22	−14	−7	16	−12	36
1,500	37	1	36	6	33	17	−13	−4	5	−6	35
1,250	27	−2	39	3	35	16	−6	−5	3	−1	34
1,000	27	−6	35	−2	28	17	5	−13	−3	8	31
750	23	−8	32	−5	15	15	15	−15	−4	14	22
500	17	−7	34	−3	0	13	18	−9	2	15	13
250	14		26		−5	10	17			10	2
Surface	14	−5	23	−3	−7	10	17	−7	4	7	0

From Tables 13 and 14 it is evident that for both summer and winter the differences between the mean relative humidities of HIGHS and LOWS at Drexel and Ellendale, the northernmost stations, are almost inappreciable but indicate for the most part a slightly greater mean relative humidity in HIGHS than in LOWS at these stations.

In winter, at the southern and eastern stations, the mean relative himidity is appreciably greater in LOWS than in HIGHS. This comparison has not been found possible for the southern stations for summer owing to insufficient observations.

VAPOR PRESSURE

The mean vapor pressures for various quadrants of HIGH and LOWS for summer and winter are shown in Figures 34 to 37, inclusive.

A striking agreement will be noted in the relative order of the curves for the various quadrants as compared with the temperature curves for corresponding quadrants. This is to be expected from the well-known relationship between the absolute humidity and temperature.

It is evident that the mean vapor pressures for both HIGHS and LOWS are appreciably greater at the southern than at the northern stations, with the differences dimishing with altitude and practically disappearing above 5 km. This latitudinal relationship in the mean vapor pressures of HIGHS and LOWS is considerably less marked, however, for LOWS than for HIGHS, particularly in the lowest levels. It is decidedly greater in summer than in winter, especially for HIGHS. The marked latitudinal variation occurring in summer instead of winter stands in opposite relationship to that found for temperature. This fact, however, is readily explained by the considerably greater difference in the capacity of air for moisture within a given range of relatively high temperatures as compared with that for the same range at lower temperatures.

The seasonal variation in the mean vapor pressures for both HIGHS and LOWS is appreciable, being somewhat greater, however, for the former than the latter.

It is evident that the range in the mean vapor pressures between the lowest and highest levels is considerably greater in LOWS than in HIGHS.

TABLE 15.—*Excess or deficiency (−) of mean vapor pressures, mb., of (A) the rear sector (second and third quadrants) of "lows" as compared with the front sector (first and fourth quadrants) of "highs" and of (B) the front sector of "lows" as compared with the rear sector of "highs"*

SUMMER

Height (m.) M. S. L.	(A) Northerly currents: Drexel, Nebr.	Ellendale, N. Dak.	Royal Center, Ind.	(B) Southerly currents: Broken Arrow, Okla.	Drexel, Nebr.	Ellendale, N. Dak.	Royal Center, Ind.
5,000					0.63		
4,500		0.99		0.05	1.11		
4,000	2.83	0.74		−1.03	1.82	1.66	
3,500	2.52	1.45		−1.32	1.81	0.86	2.59
3,000	2.52	1.45	2.45	−1.09	1.28	1.53	3.31
2,500	3.38	1.84	1.69	−0.89	1.14	1.85	3.35
2,000	3.81	2.52	2.23	−0.70	1.95	2.23	3.14
1,500	4.33	3.06	3.98	−0.80	3.31	3.15	2.61
1,250	4.11	3.26	4.42	−0.04	4.19	3.00	2.56
1,000	4.82	3.54	4.89	0.08	4.62	3.84	2.99
750	5.58	3.87	5.32	0.25	5.29	4.61	3.65
500	5.14	4.19	5.83	1.03	6.20	5.05	4.37
250			6.23	0.61			5.11
Surface	4.89	4.02	6.10	0.64	6.54	5.26	5.16

TABLE 16.—*Excess or deficiency (−) of mean vapor pressure, mb., of (A) the rear sector (second and third quadrants) of "lows" as compared with the front sector (first and fourth quadrants) of "highs" and of (B) the front sector of "lows" as compared with the rear sector of "highs"*

WINTER

Height (m.) M. S. L.	(A) Northerly currents: Broken Arrow, Okla.	Drexel, Nebr.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.	(B) Southerly currents: Broken Arrow, Okla.	Drexel, Nebr.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
4,500									0.93		
4,000		0.98						0.25	0.94		1.01
3,500		0.87	−0.46	0.52	0.50			−0.07	0.85		1.47
3,000	−1.27	0.73	−0.16	1.00	0.46			0.05	0.69	0.02	1.71
2,500	−0.74	0.70	0.40	1.26	0.77	1.25	−1.99	0.45	0.98	0.58	2.11
2,000	0.44	0.99	1.10	1.39	1.45	1.61	−1.82	0.96	1.39	0.73	2.25
1,500	2.44	1.74	1.70	1.74	2.01	2.18	1.70	1.78	1.73	2.11	2.73
1,250	2.87	2.03	2.38	1.83	2.23	2.53	2.69	2.13	2.00	3.17	2.88
1,000	2.94	2.23	2.55	1.99	2.33	2.58	4.33	2.66	2.13	4.71	3.08
750	3.24	2.45	2.81	2.19	2.37	2.53	6.08	3.23	2.55	5.84	2.86
500	3.46	2.67	3.50	2.36	2.11	2.67	6.81	3.55	2.93	6.90	2.78
250	3.51		3.56		2.17	3.02	6.76			7.23	2.65
Surface	3.53	2.79	3.49	2.41	2.23	3.05	6.75	3.38	2.91	7.54	2.62

It is evident from Tables 15 and 16 that the mean vapor pressures are appreciably greater in LOWS than in HIGHS, with the greatest differences occurring in winter in those sectors represented by section (B). Broken Arrow and Groesbeck, the southern stations, show the maximum differences in this respect.

SUMMARY

In general the results of this paper are in substantial agreement with those obtained by Blair (4) for Mount Weather, Va. Certain differences are to be expected, however, since Blair used the means of the ascents and

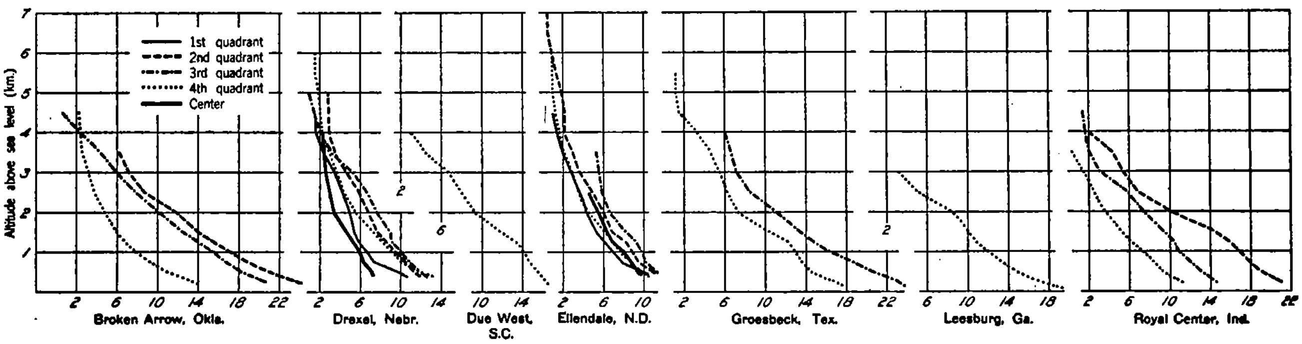


FIG. 34.—Mean vapor pressures, mb., for various heights as determined from kite observations in various quadrants of well-pronounced HIGHS during summer.

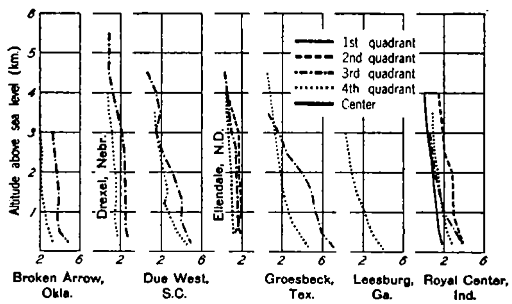


FIG. 35.—Mean vapor pressures, mb., from kite observations in winter HIGHS

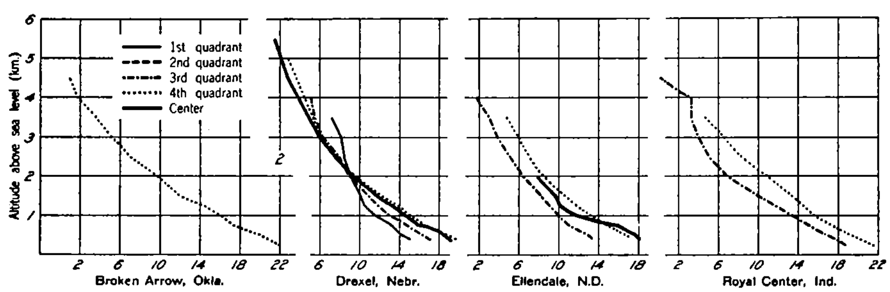


FIG. 36.—Mean vapor pressures, mb., from kite observations in summer LOWS

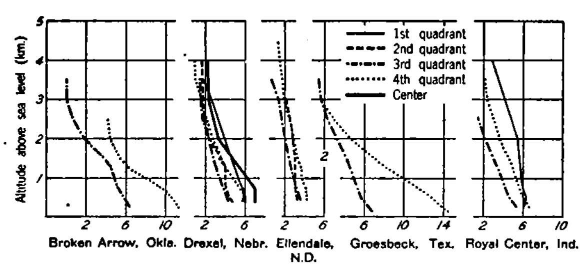


FIG. 37.—Mean vapor pressures, mb., from kite observations in winter LOWS

The negative values indicated for Broken Arrow for summer under section (B) of Table 15 may reasonably be attributed to an insufficient number of observations since both the southern stations, Groesbeck and Leesburg, while not represented in the tables, are found to agree with the northern stations in that the vapor pressures in both seasons average greater in LOWS than in adjacent sectors of HIGHS.

descents while in the present paper only the ascents are represented. Furthermore, the results shown here represent primarily the more pronounced pressure types.

The following results may be emphasized:

1. The characteristics distinguishing HIGHS from LOWS are most pronounced in their lower levels.

2. The front sector of HIGHS should not be considered as synonymous with the rear sector of LOWS nor should the

rear sector of HIGHS be so considered with respect to the front sector of LOWS, since the mean values of the various elements in these respective regions show distinct differences, which, however, decrease with elevation until they become inappreciable above 5 km.

3. Mean wind velocities for adjacent sectors of HIGHS and LOWS are greater in the latter than in the former for the same levels and seasons.

4. Mean wind velocities in HIGHS, i. e., above the gradient wind level (approximately 500 m. above ground), are greatest in their first and fourth quadrants (front sector) and least in their second and third (rear sector), whereas in LOWS they are greatest in the third and fourth quadrants and least in the first and second.

5. There is usually a rather abrupt retardation in the rate of increase of wind with elevation or in some cases even a falling off in velocity beginning at about 500 m. above ground and ending at from 1 to 2 km. This condition is considerably more pronounced in the second and third quadrants of HIGHS than in their first and fourth, whereas in LOWS it is most marked in the first and second quadrants and least in the third and fourth.

6. The mean winds are very light in the *lower* levels of the central region of HIGHS, being lighter than in any of the four quadrants. In the *upper* levels of this region, however, they increase considerably and conform closely to the mean values of the first and fourth quadrants, i. e., the region of HIGHS containing the strongest winds aloft.

7. The mean winds are relatively strong in the *lower* levels of the central region of LOWS as compared to the corresponding region of HIGHS, but in the *upper* levels they are relatively light as compared with the quadrants of LOWS containing the strongest winds, viz, the third and fourth.

8. The second and third quadrants of HIGHS contain a considerably greater change in the mean wind direction with elevation than do their first and fourth, whereas in LOWS this change is greatest in the first and second quadrants and least in the third and fourth.

9. A common mean wind direction for all quadrants of HIGHS is reached at a greater height in summer than in winter and at successively higher altitudes from northern to southern stations.

10. The average temperature lapse rate in both the front and rear sectors of HIGHS and LOWS is greater in summer than in winter, the seasonal differences being considerably greater for HIGHS than for LOWS.

11. The average lapse rate is greater in LOWS than in the adjacent sectors of HIGHS for the same season, the differences being appreciably greater in winter than in summer.

12. In summer, LOWS average *warmer* than the adjacent sectors of HIGHS, the differences becoming progressively smaller from northern to southern stations and from lower to higher altitudes.

In winter, LOWS average *warmer* than HIGHS at the northern stations but generally *colder* at the *southern* and *eastern* stations, in their *upper* levels, particularly in their rear sector as compared with the front sector of HIGHS.

13. The front sector of HIGHS in winter averages colder than the rear to at least 5 km., the differences *decreasing* from northern to southern stations. For the same season the front sector of LOWS averages warmer than the rear to at least 4 km., however, in this case the differences *increase* from northern to southern stations.

14. The differences between the mean relative humidities for adjacent sectors of HIGHS and LOWS at *northern* stations are almost inappreciable, but slightly *lower* humidities are indicated, in general, for LOWS than for HIGHS in both seasons. The opposite relationship is found, however, at the *southern* and *eastern* stations in winter, where the relative humidities average *higher* in LOWS than in HIGHS.

15. The relative humidity in HIGHS and in LOWS at the *northern* stations averages a little higher in winter than in summer, whereas the opposite relationship occurs in the case of HIGHS at the southern stations.

16. The relative humidity in the *upper* levels of HIGHS averages highest in the second quadrant and lowest in the central region. In general, at all levels, it averages higher in the fourth quadrant of HIGHS than in the third, at the northern stations but the opposite relationship occurs at the southern stations.

17. The mean vapor pressures in both seasons are appreciably greater in LOWS than at the same levels of the adjacent sector of HIGHS.

18. The mean vapor pressures in HIGHS and in LOWS are greater at the southern stations than at the northern for the same seasons and levels. This latitudinal variation is appreciably less for LOWS than for HIGHS in both seasons.

19. The mean vapor pressures of the front sector of HIGHS average lower than those of their rear sector both at the northern and southern stations in both seasons, whereas in LOWS the mean values are, in general, lowest in the rear sector. These differences, in both pressure systems, diminish with altitude.

20. It was found, in general, that the fundamental characteristics as shown by the mean values for the various quadrants of HIGH and LOWS, as herein found, are in substantial agreement with the results of other investigators in this country and in Germany.

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